

THE  
PROCEEDINGS  
OF THE  
COLORADO  
SCIENTIFIC SOCIETY

---

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**OFFICIAL PART.**

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**ABSTRACT OF MINUTES  
FOR THE YEAR 1897.**

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**ONE HUNDRED AND FORTY-SECOND REGULAR MEETING.**

January 4th, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

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Thirteen persons were present.

A vote of thanks was tendered the retiring Secretary for his work during the past year.

Professor Patton acknowledged the receipt of minerals sent to the State School of Mines for exchange.

COMMUNICATIONS.—Professor Palmer read a paper on “Argon and Helium in the Periodic Sequence.” Discussed by Professors Chauvenet, van Diest and Dr. Austin.

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**ONE HUNDRED AND FORTY-THIRD REGULAR MEETING.**

February 1st, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*



Twelve persons were present.

Messrs. van Diest, Austin and Jones submitted in writing the following proposed amendments to the By-Laws:

WHEREAS, It appears that the first Monday in the month is a busy day for many members, preventing their attendance at the meetings, and as Saturday would be more convenient to many:

*Be it Resolved*, That in Section 1 of the By-Laws, Saturday be substituted for Monday, the amended By-Law to read:

The regular meetings of the Society shall be held on the first Saturday of each month. When this day falls on an official holiday, the meeting shall be held on the next following Saturday.

COMMUNICATIONS.—Mr. G. M. Gouyard read a paper on "The Magnetic Separation of Sulphide Ore." Discussed by Messrs. Hills and Ruthenberg.

ONE HUNDRED AND FORTY-FOURTH REGULAR MEETING.

March 1st, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Fourteen persons were present.

The proposed amendment to the By-Laws, changing the meetings from the first Monday to the first Saturday in the month, notice of which was announced to members by circular, was submitted to vote of the meeting and carried.

The advisability of holding a *conversazione* at the meeting of April 3 was discussed, and it was decided to carry out the suggested program. The following committee of arrangements was appointed: Messrs. Furman, Vezin and Ward.

COMMUNICATIONS.—Prof. H. B. Patton read a paper on “Crater Lake, Oregon.” Discussed by Dr. Austin and R. C. Hills.

Professor Patton, referring to his previous paper on “Spherulites,” stated that he was preparing a short paper treating on the subject. He made some additional remarks on this topic, illustrating them by a fine collection of specimens of all sizes, from that of a marble up to that of a man’s head.

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ONE HUNDRED AND FORTY-FIFTH REGULAR MEETING.

April 3d, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

Nine persons were present.

As suggested, this meeting was of a social character. The members, upon arriving at the rooms, found the usual appearance temporarily changed. Tables laden with delicacies were arranged down the middle of the room, and a social time was enjoyed.

COMMUNICATIONS.—Mr. L. S. Austin read a paper on “A Recent Assay Balance.” Discussed by Messrs. Collins and Jones.

Mr. R. C. Hills read a paper on “The Oscura Mountain Meteorite.”

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ONE HUNDRED AND FORTY-SIXTH REGULAR MEETING.

May 1st, 1897.

In the Society Rooms, Boston Building.

*The President in the Chair.*

---

Eight persons were present.

COMMUNICATIONS.—Mr. B. B. Lawrence read a paper on the History, Development and Operation of the "Pelican Mine."

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ONE HUNDRED AND FORTY-SEVENTH REGULAR MEETING.

June 5th, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Twenty-three persons were present.

COMMUNICATIONS.—Professor Jones read a paper on "The Action of Ferric Sulphate on Metals in Corrosive Mine Waters." Discussed by E. Le Neve Foster, E. B. Kirby and Philip Argall.

Henry A. Vezin read a paper on "A Laboratory Jig." Discussed by Professor Kirby and Professor Furman.

Dr. W. L. Austin read a paper on "Bandai-San Crater."

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ONE HUNDRED AND FORTY-EIGHTH REGULAR MEETING.

September 11th, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

Eight persons were present.

The election by the Executive Board of the following gentlemen to membership was announced:

Mr. William Francis Tindall, chemist of the Metallic Extraction Company, Cyanide, Colo.

Mr. Robert S. Stockton, Assistant Professor of Mathematics, State School of Mines, Golden, Colo.

Mr. Frederick Horace Minard, chemist of the G. & S. Recovery Company, Denver, Colo.

In consideration of long and valuable services rendered to the Society since its organization, Prof. P. H. van Diest was elected an honorary member.

The Executive Committee submitted an amendment to Section 14 of the By-laws, to be voted on at the next meeting, as follows (the emendation is in *italics*):

“The amount of entrance fee and annual dues shall be determined by the Executive Committee.

“The annual dues are payable before May 1st of each year. All members or associates whose annual dues are unpaid May 1st shall be officially notified by the Treasurer in writing.

“Members and associates whose annual dues are unpaid September 1st shall cease to receive the publications of the Society, *and their names shall be posted in the Society's rooms.* Should the dues be still unpaid December 31st, then such delinquents shall be dropped from the rolls of the Society.

“*Provided, however,* that the Executive Committee may reinstate such persons upon application and payment by them of all unpaid dues.

“Members and associates not in arrears may become life members and life associates upon payment into the Treasury of the sum of one hundred dollars, and such life members and associates shall be exempt from the future payment of annual dues.

At the suggestion of the Secretary, the following question was discussed in an informal way:

In blast furnace smelting for lead, why does lead pass into

the matte; why is not the matte a pure iron sulphide (and copper sulphide when copper is present); and, since lead is always found in the matte formed in such furnaces, what conditions regulate the percentage of the metal in these mattes?

It is well known that some mattes are quite low in lead while in other cases the percentage is quite high.

A discussion followed in which Dr. Austin and Mr. Argall took part, but owing to the lack of specific data, it was decided to discuss the question at some future meeting.

Mr. Henry A. Vezin then gave an informal talk on a somewhat unique method of concentration in use in a mill at Empire, in which, with very imperfect and inexpensive machinery, remarkable results were obtained.

In the discussion which followed, Dr. Austin described the cheapest concentration process or plant which he had ever seen, practiced on copper ores in Japan, in which ore containing 1 per cent. copper was profitably handled.

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ONE HUNDRED AND FORTY-NINTH REGULAR MEETING.

October 2d, 1897.

In the Society Rooms, Boston Building.

---

*Ex-President Chauvenet in the Chair.*

---

Eleven persons were present.

The Acting Secretary announced the election of Mr. James Underhill as a member by the Executive Committee.

COMMUNICATIONS.—Dr. Richard Pearce read a paper on "Notes on a Peculiar Occurrence of Tellurium with Vanadium in Gold Ore, from the Great Boulder Main Reef Mine," Western Australia.

The paper was illustrated by a remarkable specimen which Dr. Pearce presented to the Society.

Dr. N. Olof Holst, of Stockholm, Sweden, was present as a guest of the Society.

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ONE HUNDRED AND FIFTIETH REGULAR MEETING.

November 6th, 1897.

In the Society Rooms, Boston Building.

---

*Ex-President Palmer in the Chair.*

Fourteen persons were present.

The Acting Secretary announced the election to membership by the Executive Committee of Prof. Charles W. Comstock, of Denver; Milton C. Whitaker, of Boulder.

COMMUNICATIONS.—D. Wm. P. Headden read a paper on "Some Products Found in the Hearth of An Old Furnace Upon the Dismantling of the Trethellen Tin Works, Truro, Cornwall."

This paper was illustrated by a number of specimens and was discussed by Dr. Richard Pearce, J. A. Porter and others.

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ONE HUNDRED AND FIFTY-FIRST REGULAR MEETING.

December 4th, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

Sixteen persons were present.

The Acting Secretary announced the election to membership, by the Executive Committee, of F. C. Knight, of Denver; Dr. Charles Pret, of La Plata.

Nominations for officers of the Society for the ensuing year were made as follows:

President . . . . .	W. L. Austin.
First Vice-President . . . . .	B. B. Lawrence.
Second Vice-President . . . . .	E. Le Neve Foster.
Recording Secretary . . . . .	Charles W. Comstock.
Corresponding Secretary and Librarian, . . . . .	P. H. van Diest.
Treasurer . . . . .	Henry A. Vezin.
Curator . . . . .	R. C. Hills.

For members of the Executive Committee:

W. Byrd Page,	J. A. Porter,
Richard Pearce,	T. E. Schwarz,
W. S. Ward,	Henry E. Wood,
H. van F. Furman,	C. H. Livingstone,
E. B. Kirby,	R. C. Hills.

Mr. Lawrence moved that a Committee on Ways and Means, to promote interest in the Society, be appointed by the President. This motion was discussed by Messrs. Austin, Chauvenet, Ward, Furman, Kirby and others. The chair appointed as members of this committee: Messrs. Pearce (chairman), Lawrence, Chauvenet, Wood and Ward.

The President announced that this Society would have a dinner this year, and appointed Messrs. Lawrence, Hale and Furman as the committee on annual dinner.

#### ANNUAL MEETING.

December 20th, 1897.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Eleven persons were present.

The Acting Secretary announced the election to membership, by the Executive Committee, of Mr. T. L. Wilkinson, of Denver.

The Acting Secretary read the report of the Committee on Ways and Means, for the advancement of the interests of the Society, appointed by the President at the meeting of December 4th, 1897. The report was discussed by several members.

The Treasurer read his preliminary report, and the chair appointed Mr. H. E. Wood and Mr. C. H. Livingstone as committee to audit the Treasurer's accounts and submit their report at the next regular meeting.

The Acting Secretary read the reports of the Acting Recording Secretary (the regularly elected Secretary having resigned) and of the Corresponding Secretary and Librarian, who was absent.

Upon report of the tellers appointed by the President to canvass the ballots, the President announced the election of the following gentlemen as officers of the Society for the year 1898:

President	W. L. Austin.
First Vice-President	B. B. Lawrence.
Second Vice-President	E. Le Neve Foster.
Recording Secretary	C. W. Comstock.
Corresponding Secretary and Librarian	P. H. van Diest.
Treasurer	Henry A. Vezin.
Curator	R. C. Hills.

EXECUTIVE COMMITTEE.

H. van F. Furman,	Richard Pearce,
Henry E. Wood,	W. Byrd Page,
J. A. Porter.	



ABSTRACT OF MINUTES.

The President, W. L. Austin, then gave a description of some interesting copper deposits which he had recently visited.

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ABSTRACT OF MINUTES

FOR THE YEAR 1898.

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ONE HUNDRED AND FIFTY-SECOND REGULAR MEETING.

January 3d, 1898.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Seventeen persons were present.

The Secretary announced the election to membership, by the Executive Committee, of F. S. Watkins, of Denver; C. W. Davis, of Colorado Springs, and W. B. Stoddard, of Golden.

A letter from the Society of Colonial Wars, submitting a proposition to share the rooms of this Society at a rental of \$15 per month, was read, with the recommendation of the Executive Committee that a counter-proposition be made, asking \$25 per month, of which \$10 should be added to the salary of the Assistant Librarian. After some discussion, it was voted that the recommendation of the Executive Committee be adopted, and the Secretary was instructed to communicate with the Society of Colonial Wars to this effect.

It was unanimously voted that the Secretary be instructed to write to the University Club of Denver, thanking the officers and members of that organization for their courtesy in throwing open their house to this Society on the occasion of its annual banquet, December 29, 1897.

The President then appointed the following committees:

**PUBLICATION COMMITTEE.**

R. C. Hills. Henry A. Vezin.

H. van F. Furman.

The President, *ex-officio*.

The Secretary, *ex-officio*.

**ENTERTAINMENT COMMITTEE.**

Regis Chauvenet. . . . . B. B. Lawrence.

Irving Hale.

COMMITTEE ON PAPERS.

Philip Argall. Henry E. Wood.

C. H. Livingstone.

## WAYS AND MEANS COMMITTEE.

J. A. Porter. E. B. Kirby.

T. L. Wilkinson. Henry Fulton.

C. S. Palmer. B. B. Lawrence.

D. W. Brunton.

COMMUNICATIONS.—Professor Kirby read a paper on "The Sampling of Ore in Place."

Dr. Richard Pearce read a paper on "Notes on the Occurrence of Rhodocrosite in the 'Original Mine,' Butte, Montana."

Dr. Pearce presented a very fine specimen of this mineral to the Society.

ONE HUNDRED AND FIFTY-THIRD REGULAR MEETING.

February 5th, 1898.

**In the Society Rooms, Boston Building.**

*The President in the Chair.*

---

Ten persons were present.

COMMUNICATIONS.—Milton C. Whitaker read a paper, entitled "An Olivinite Dike of the Magnolia District and the Associated Pierotitanite."

Mr. Whitaker presented to the Society a number of specimens illustrating this paper.

Arthur L. Collins read a paper on "Notes on the Occurrence of Carbonic Acid Gas in Certain Veins of Gilpin County, Colorado."

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ONE HUNDRED AND FIFTY-FOURTH REGULAR MEETING.

March 5th, 1898.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Nineteen persons were present.

COMMUNICATIONS.—Thomas L. Wilkinson read a paper on "Gas and Oil Engines." Discussion by Henry A. Vezin, W. L. Austin, L. C. Hills and others.

---

ONE HUNDRED AND FIFTY-FIFTH REGULAR MEETING.

May 7th, 1898.

In the Society Rooms, Boston Building.

*Second Vice-President E. Le Neve Foster in the Chair.*

---

Eleven persons were present.

COMMUNICATIONS.—In the absence of P. H. van Diest, his paper on "A Mineralogical Mistake" was read by the Acting Secretary.

---

ONE HUNDRED AND FIFTY-SIXTH REGULAR MEETING.

June 6th, 1898.

In the Society Rooms, Boston Building.

---

*Past President J. A. Porter in the Chair.*

---

Fourteen persons were present.

The Chairman announced the election to membership by the Executive Committee of F. P. Wood and J. N. Stahl, both of Boulder.

COMMUNICATIONS.—Prof. Richard Pearce read papers on "Notes on the Occurrence of Selenium with Pyrite Rich in Gold and Silver" and "Remarks on a Gold Nugget from Montana."

Mr. Pearce also presented to the Society a specimen of huebnerite from the Gagnon Mine, Butte, Montana.

Mr. J. A. Porter presented some specimens of gold taken from the Smuggler-Union Mine.

---

ONE HUNDRED AND FIFTY-SEVENTH REGULAR MEETING.

October 1st, 1898.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Eleven persons were present.

COMMUNICATIONS.—C. W. Comstock read a paper on "Note on the Resistance of Materials Subjected to Compressive Stress." This was discussed briefly by F. S. Watkins.

Prof. Richard Pearce presented to the Society a specimen of mineral broken from the surface rock near the summit of Sierra Blanca, and sent to him by Professor van Diest. Dr. Pearce gave the results of his examination of this mineral, and expressed his belief that it was a species not heretofore observed.

Dr. Pearce presented to the Society two specimens of sylvanite— one from Clear Creek and one from Gilpin County—and a specimen of turquoise from the Last Chance Mine at Creede.

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ONE HUNDRED AND FIFTY-EIGHTH REGULAR MEETING.

November 5th, 1898.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Nine persons were present.

Prof. L. S. Austin described the construction and operation of a matte smelting plant under his supervision at Buena Vista, Colorado.

This paper was discussed at length by Messrs. Kirby, W. L. Austin, Livingstone and Vezin.

## ONE HUNDRED AND FIFTY-NINTH REGULAR MEETING.

December 3d, 1898.

In the Society Rooms, Boston Building.

---

*Second Vice-President E. Le Neve Foster in the Chair.*

---

Eleven persons were present.

The following nominations for officers for the year 1899 were made:

President	. . . . .	E. Le Neve Foster.
First Vice-President	. . . . .	J. A. Porter.
Second Vice-President	. . . . .	E. B. Kirby.
Recording Secretary	. . . . .	C. W. Comstock.
Corresponding Secretary and Librarian,	. . . . .	P. H. van Diest.
Treasurer	. . . . .	Henry A. Vezin.

For members of the Executive Committee:

W. L. Austin,	Regis Chauvenet,
R. C. Hills,	Richard Pearce,
F. S. Watkins.	

Moved by E. B. Kirby and seconded by H. A. Vezin that the Society have an annual dinner; that the chairman appoint a committee to arrange for it, and that the Secretary be instructed to send out circulars to the members notifying them of this action of the Society. Carried.

The chairman then appointed the following committee on annual dinner: B. B. Lawrence, H. V. Pearce, Harry A. Lee and T. L. Wilkinson.

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ANNUAL MEETING.

December 17, 1898.

In the Society Rooms, Boston Building.

---

*Second Vice-President E. Le Neve Foster in the Chair.*

---

Nine persons were present.

The chairman then appointed W. H. Bunce and Harry A. Lee tellers to canvass the ballots for officers. Upon their report the following were declared elected for the year 1899:

President	. . . . .	E. Le Neve Foster.
First Vice-President	. . . . .	J. A. Porter.
Second Vice-President	. . . . .	E. B. Kirby.
Secretary	. . . . .	C. W. Comstock.
Corresponding Secretary and Librarian	. . . . .	P. H. van Diest.
Treasurer	. . . . .	H. A. Vezin.

EXECUTIVE COMMITTEE.

W. L. Austin,	Regis Chauvenet.
R. C. Hills.	Richard Pearce.
F. S. Watkins.	

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ABSTRACT OF MINUTES

FOR THE YEAR 1899.

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ONE HUNDRED AND SIXTIETH REGULAR MEETING.

January 14th, 1899.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

Seven persons were present:

The chair appointed Messrs. C. H. Livingstone and Henry E. Wood a committee to audit the Treasurer's accounts for 1897 and 1898:

B. B. Lawrence introduced a resolution that the Society petition the Senators and Representatives of the State of Colorado in the United States Congress to support the bill providing for a Division of Mines and Mining in the United States Geological Survey, which motion was adopted.

COMMUNICATIONS.—L. S. Austin described and showed to the members present a very fine balance made in Denver by Smith & Thompson, and used for checking weights. This balance is said to be sensitive to  $\frac{1}{1000}$ th of a milligramme.

R. C. Hills called the attention of the members to a very fine collection of minerals recently presented to the Society by J. A. Porter, and to a number of choice specimens presented by A. Raht, J. L. Jerome and Phillip Rearden.

Mr. Hills presented a specimen of uranochre, a pseudomorph of native copper after azurite, and a specimen of byerite from Middle Park. He described the occurrence of the byerite, and gave the results of several analyses by different persons.

A vote of thanks to these gentlemen for their donations to the Society was proposed and passed.

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ONE HUNDRED AND SIXTY-FIRST REGULAR MEETING.

March 4th, 1899.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Eight persons were present.



The Secretary announced the election, by the Executive Committee, of Barry Hogarty, of Boulder, as a member, and Henry T. Rogers, of Denver, as an associate member.

COMMUNICATIONS.—Barry Hogarty read a paper on "The Andesite of Mount Sugar Loaf, Boulder County, Colorado."

This paper was discussed briefly by R. C. Hills and E. B. Kirby.

---

ONE HUNDRED AND SIXTY-SECOND REGULAR MEETING.

April 1st, 1899.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Ten persons were present.

COMMUNICATIONS.—E. B. Kirby read a paper on "Testing and Sampling Placer Deposits."

This paper was discussed by Regis Chauvenet, R. C. Hills, E. Le Neve Foster and Henry A. Vezin.

---

ONE HUNDRED AND SIXTY-THIRD REGULAR MEETING.

May 6th, 1899.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Eight persons were present.

COMMUNICATIONS.—T. L. Wilkinson read a paper entitled "The Self-Cooling Condenser."

This paper was discussed briefly and informally by Philip Argall, Henry A. Vezin and H. van F. Furman.

---

ONE HUNDRED AND SIXTY-FOURTH REGULAR MEETING.

November 4th, 1899.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Nine persons were present.

The Secretary announced the election to membership of Donald W. Campbell, of Denver.

Mr. Wm. P. Headden described his work in the analysis of a sandstone containing uranium and vanadium sent to him by Harry A. Lee. He supposed the mineral containing these metals to be camotite.

Harry A. Lee described the occurrence of this sandstone. It came from a point about a half mile from the town of Placerville, in San Miguel county, and is supposed to contain the jura-trias. He presented some specimens of this sandstone to the Society, and exhibiting to those present a photograph giving a very good idea of the mode of occurrence.

R. C. Hills stated that he had examined camotite under a microscope and believed that it was not a single mineral, but a mixture of two. He further stated that the sandstone in question is the La Plata sandstone, occurring near the jurassic. In the San Juan, the jurassic is unconformable on the triassic and is thus comparatively easy to identify. Further, this is the only place in the Rocky Mountains where fossils have been found in the upper triassic.

Following these remarks, there was a brief discussion on uranium and vanadium minerals and their market values, by Messrs. Chauvenet, Headden, Hills and Lee.

Mr. Lee then showed a specimen of coal containing bornite, from New Annan, Colchester County, Nova Scotia. Its analysis is:

Cu.....	34.6 per cent.
Au.....	\$3.90 per ton.
Ag.....	9 ozs. per ton.

It occurs in quite large kidneys, between a limestone and a shale, but there is not enough of it to make a mine.

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ONE HUNDRED AND SIXTY-FIFTH REGULAR MEETING.

December 2d, 1899.

In the Society Rooms, Boston Building.

---

*The President in the Chair.*

---

Six persons were present.

In the absence of a quorum no business was transacted except the nomination of officers for the ensuing year.

The following nominations were made:

President . . . . .	E. Le Neve Foster.
First Vice-President . . . . .	Frederick Knight.
Second Vice-President . . . . .	A. L. Collins.
Treasurer . . . . .	Henry A. Vezin.
Secretary . . . . .	C. W. Comstock.
Corresponding Secretary and Librarian . . . . .	T. L. Wilkinson.

For members of the Executive Committee:

G. L. Cannon,	Regis Chauvenet,
R. C. Hills,	Harry A. Lee,
Richard Pearce.	

ABSTRACT OF MINUTES.  
FOR THE YEAR 1900.

ONE HUNDRED AND SIXTY-SIXTH REGULAR MEETING.

January 6th, 1900.

In the Society Rooms, Boston Building.

*The President in the Chair.*

Eleven persons were present.

The chair appointed Messrs. D. W. Campbell and L. S. Austin tellers to count the ballots for officers for the year 1900. Upon their report the following were declared unanimously elected:

President . . . . .	Ernest Le Neve Foster.
First Vice-President . . . . .	Frederick Knight.
Second Vice-President . . . . .	A. L. Collins.
Treasurer . . . . .	Henry A. Vezin.
Secretary . . . . .	C. W. Comstock.
Corresponding Secretary and Librarian	T. L. Wilkinson.

EXECUTIVE COMMITTEE.

G. L. Cannon,	Regis Chauvenet,
R. C. Hills.	Harry A. Lee.
Richard Pearce.	

The Secretary announced the election to membership, by the Executive Committee, of Louis B. Cass, of Ouray.

COMMUNICATIONS.—H. van F. Furman then read a paper entitled "Notes on Mining and Smelting in the State of Durango, Mexico." This paper was discussed informally by everyone present.

## ONE HUNDRED AND SIXTY-SEVENTH REGULAR MEETING.

February 3d, 1900.

In the Society Rooms, Boston Building.

---

*W. L. Austin, Past President in the Chair.*

---

Thirteen persons were present.

COMMUNICATIONS—Mr. Charles S. Palmer read a paper entitled "Outline of the Theoretical Chemistry of Copper."

This paper was discussed by nearly everyone present.

A vote of thanks to Mr. Palmer for his interesting and instructive paper was proposed and carried.

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## ONE HUNDRED AND SIXTY-EIGHTH REGULAR MEETING.

March 3d, 1900.

In the Society Rooms, Boston Building.

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*The President in the Chair.*

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Twelve persons were present.

Mr. Richard Pearce exhibited some specimens of gold ore, illustrating the genesis of gold nuggets, and made a few remarks relating to this subject. These remarks were a continuation of a previous note by Mr. Pearce on the same subject.

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## ONE HUNDRED AND SIXTY-NINTH REGULAR MEETING.

April 14th, 1900.

In the Society Rooms, Tabor Opera House Building.

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*The President in the Chair.*

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Seven persons were present.

Mr. Cannon reported progress in the work of the committee appointed to confer with other scientific societies on the subject of consolidation.

There was an informal discussion of several subjects.

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ONE HUNDRED AND SEVENTIETH REGULAR MEETING.

May 5th, 1900.

In the Society Rooms, Tabor Opera House Building.

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*Regis Chauvenet, Past President, in the Chair.*

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Eleven persons were present.

Mr. Richard Pearce presented to the Society two specimens of covellite, one from San Juan County and one from Montrose County, Colorado. It is a rare mineral in this State

COMMUNICATIONS.—Mr. F. R. Carpenter read a paper on "Matte Smelting in the Black Hills." Discussed by Messrs. Chauvenet, Richard Pearce and W. L. Austin.

ONE HUNDRED AND SEVENTY-FIRST REGULAR MEETING.

September 1st, 1900.

In the Society Rooms, Tabor Opera House Building.

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*The President in the Chair.*

Sixteen persons were present.

COMMUNICATIONS.—Mr. W. L. Austin read a paper entitled "Notes on Mexican Copper Deposits."

This was discussed by Messrs: R. C. Hills, Philip Argall, A. F. Wuensch, J. B. Farish, Richard Pearce and E. Le Neve Foster.

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ONE HUNDRED AND SEVENTY-SECOND REGULAR MEETING.

October 6th, 1900.

In the Society Rooms, Tabor Opera House Building.

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*The President in the Chair.*

Ten persons were present.

COMMUNICATIONS.—Mr. E. C. van Diest described some mineral deposits near Silverton, Colorado.

These were discussed at length by Messrs. W. L. Austin, W. S. Ward and E. Le Neve Foster.

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ONE HUNDRED AND SEVENTY-THIRD REGULAR MEETING.

December 1st, 1900.

In the Society Rooms, Tabor Opera House Building.

*The President in the Chair.*

Seven persons were present.

The application of G. C. Hewett, mining engineer, of Colorado Springs, for membership, was presented, and Mr. Hewett was elected.

COMMUNICATIONS.—Mr. G. L. Cannon, jr., read a paper on "The Problems of the Local Quaternary."

This paper was discussed by Messrs. Watkins, Vezin and Foster.

The following nominations were made for officers for the year 1901:

President	E. Le Neve Foster.
First Vice-President	H. van F. Furman.
Second Vice-President	C. H. Livingstone.
Treasurer	H. A. Vezin.
Secretary	C. W. Comstock.
Corresponding Secretary and Librarian	T. L. Wilkinson.
Curator	R. C. Hills.

For members of the Executive Committee:

W. L. Austin,	G. L. Cannon, jr.,
Harry A. Lee,	Richard Pearce,
F. S. Watkins.	

The chairman then appointed the following committees:

On Annual Dinner.—T. L. Wilkinson, C. W. Comstock.

Auditing Committee.—F. S. Watkins, C. W. Comstock.

## ANNUAL MEETING.

December 15th, 1900.



XXX

ABSTRACT OF MINUTES.

In the Society Rooms, Tabor Opera House Building.

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*The President in the Chair.*

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Seven persons were present.

The President appointed Messrs. F. L. Clerc and F. S. Watkins tellers to canvas the ballots.

Upon report of the tellers, the following were declared elected:

President	. . . . .	E. Le Neve Foster.
First Vice-President	. . . . .	H. van F. Furman.
Second Vice-President	. . . . .	C. H. Livingstone.
Recording Secretary	. . . . .	Henry A. Vezin.
Corresponding Secretary and Librarian	. . . . .	C. W. Comstock.
Treasurer	. . . . .	T. L. Wilkinson.
Curator	. . . . .	R. C. Hills.

EXECUTIVE COMMITTEE.

W. L. Austin,	G. L. Cannon, jr.
Harry A. Lee,	Richard Pearce,
F. S. Watkins.	

# THE NATURE OF THE CHEMICAL ELEMENTS.

(EIGHTH PAPER.)

## ARGON AND HELIUM IN THE PERIODIC SEQUENCE.

BY CHARLES SKEELE PALMER, PH.D.

Professor of Chemistry, University of Colorado.

Read at Meeting, January 4, 1897.

### I. ARGON AND HELIUM.

It is now several years [Brit. Ass'n. Aug., 1894,] since the chemical world was startled by the preliminary announcement that the atmosphere contains a new ingredient, viz.: *Argon*, in notable proportions. [Schloesing. *C. Rend.* p. 520, Oct. 14, 1895. % by vol.=0.935 of 1%]. The first public announcement with details, was given Dec. 31, 1894, by the discoveries of Lord Rayleigh and Professor Ramsay. The description, up to date, relates to the following physical properties, viz.:

(a) The density. [19.9]. (b) The amenability to the gas law.

(c) The liquefaction. [M. P. =  $-189.6^{\circ}$ ; B. P. =  $-187^{\circ}$ ].

(d) The solubility in water. [4.05 in 100, at  $13.9^{\circ}$ ].

(e) The identity of the "mol. wt." with the "at. wt." by the method of sound waves. ["Sp. Ht." = 1.66].

(f) The specific refractive energy. [ $\frac{\text{Refrac Argon}}{\text{Air}} = 0.961$ ].

(g) The viscosity. [Air = 1; Argon = 1.21].

(h) The spectrum of argon. [See Crookes, Kayser, Runge and Paschen].

(i) The % vol. in the atmosphere and many other gases, and also in liquids and solids.

## THE CHEMISTRY OF ARGON.

- (1) It is not acted upon by sparking with N, O, or H, in acid or alkali.
- (2) It is not "sparked" by H, Na, or KOH, or soda-lime.
- (3) It is not acted on by O, Cl, Br, P, S, Te,  $\text{Na}_2\text{O}_2$ ,  $\text{Na}_2\text{S}_2$ , or  $\text{KNmO}_4$ .
- (4) It is not acted upon by  $\text{HNO}_3$  and  $\text{HCl}$ .
- (5) It is not acted upon by "Pt. Black" and O.
- (6) It is not acted on by nascent F.
- (7) The supposed compounds of argon with  $\text{CS}_2$  and  $\text{C}_6\text{H}_6$  (Berthelot) are shown by Dorn and Erdmann to be impure mixtures.
- (8) The supposed compound of argon with C is shown to be CO. [Ramsay].
- (9) The asserted "occlusion" by Pt. on sparking is not a regular process but probably occurs. [Crookes].
- (10) There is a possible hydrate of argon with ice. [P. Villard. *C. Rend*, Aug. 17, 1896].

The spectroscopic examination of argon led to the discovery of *Helium*, in rare minerals of uranium, yttrium, or thorium composition.

At first there was a supposed identity between some of the lines of argon and helium; this is now regarded as a similarity at most. Helium has been tested and measured, and fitted with a set of physical and chemical properties which place it in the same exceptional class with argon.

Both are peculiar in giving results showing the identity of the "mol. wt." and the "at. wt." Both show a peculiar "double-ness," of spectrum, and helium has probably been fractioned by diffusion. The *average* density of helium is about 2.2; it has not been liquefied. [Crit. Temp.  $\text{H} = -234^\circ$ —B. P. =  $-243^\circ$ ].

Now, here are two new kinds of genuine gaseous matter, possessed of definite physical properties, but absolutely negative as regards active chemical reaction; further in both the "mol. wt." equals "at. wt."

One, argon, ["at. wt."=39.08], has no apparent place in the periodic sequence; the other *helium*, (assuming for provisional convenience that it is not a mixture); ["at. wt."=4.4] can fit in to the periodic sequence in numerical relation, but this seems forced unless some natural relation shall become visible.

It should be noticed that the term "atomic weight" is anomalous and only excusable on the explanation that it is the weight of the unit physical molecule referred to *the  $\frac{1}{2}$  molecule of gaseous hydrogen as unity*.

## II. THE PERIODIC SEQUENCE.

No extended remarks are needed here. I will only say that I still use the order given to the Society Aug. 4, 1890. [See table]. Their order was then supported by a number of facts; it then seemed the best available arrangement; it seems to me to be so still.

Now, what is the Periodic Sequence, and what does it state? To this I would reply:

(1) It emphasizes the arrangement of all the elements in *independent, short and long series*.

(2) There are parts of eight series. Considering the 2nd, 3rd, 4th, 5th, 6th and 7th, *each series begins with an alkali and ends with a halogen*, with appropriate intermediate gradation and "orientation."

(3) The end numbers are light, the middle ones heavy in Sp. Gr. in each series.

(4) There is a repeated sequence in "normal" valence tendency.

(5) All this is in regular order of the ascending at. wt.

(6) In *general*, the volatile elements and those having volatile compounds are found in the right half, *i. e.*, those amenable directly to the rule of Avogadro; while the non-volatile elements, *i. e.*, those amenable directly to the Dulong-Petit law of At. Ht. are on the left.

(7) The general indications are that *paramagnetism* prevails to the left and above, and *diamagnetism* to the right and below.

(8) There are undoubted anomalies, e. g. tellurium, actual at. wt. =  $128 \pm$  : — the order of Co. and Ni; — the fractionation of  $\text{Di} = \text{Neo} \cdot \text{Di} + \text{Pr} \cdot \text{Di}$ .

But on the *whole*, the Periodic Sequence is a kind of a great generalization of relations, certainly convenient, and almost indispensable for *comparative chemistry*—a kind of an analogue to “Bode’s Law” in Astronomy, but a thousand times more complete, more consistent, more inter-dependent in parts. Thus, in a few words, the Periodic Sequence defines—incompletely, to be sure, but very good as far as it goes—an element as a function of:

- (a) The at. wt.
- (b) The valence (particular).
- (c) The at. vol.
- (d) The inherent basiferous or acidiferous character.

This is a definition gained by all the good work done up to date and is not to be underestimated.

But no scientific student, who loves to avoid the spirit of dogmatism and extreme conservatism, or who would keep himself open and sensitive to the perception of new truth, no such ever will for a moment assert that our great Periodic Sequence is more than a great register of truth found out. Of course it must be liable to modification. Does it require modification at present? We think not. Argon and helium apparently come in very conveniently to fill the *gaps between the series*:—gaps which have been overlooked and which are significant. But let us examine the possibilities.

### III. THE POSSIBILITIES OF ARGONOID CHEMISTRY.

There are four obvious possibilities regarding argon and helium, viz.:

- (1) They may be of a nature essentially like the elements

embraced in our present Periodic Sequence ; and here they may essentially be  $\begin{cases} a\text{--active} \\ b\text{--inactive.} \end{cases}$

(2) They may belong to an order of elements essentially *distinct* from the elements embraced in our present Periodic Sequence, and then they may be  $\begin{cases} a\text{--active} \\ b\text{--inactive.} \end{cases}$

Now, of these four possibilities, as implied in the title of this paper, we are concerned for the authority of the Periodic Sequence only on the supposition that argon and helium are of the same sort as our other elements. But as they are *not active*, as other elements are, they are therefore referred to the "inactive" class.

What does this mean? What kind of recognition can argon and helium receive without doing violence to any observed fact, and with all due justice to sound common sense?

The answer suggests most interesting possibilities.

#### IV. "A PRIORI."

The consideration of the fact that our chemical compounds may for convenience be classified roughly under the head of *acids*, and *bases*, and *salts*, lead to some strange anticipations. There are known acidiferous elements, and basiferous elements ; why not look for salt-like elements?

Now, we have chemical ambiguity of several sorts : thus (*a*) nitrogen reduced by hydrogen is a *base* in the ammonium compound; nitrogen oxidized by oxygen is an *acid* in the nitrates. (*b*) Aluminum hydroxide acts on a base with strong acids, and as an acid with strong bases. (*c*) The "VIII groups," so called. (Fe. Co. Ni.), (Ru. Rt. Pd.), (Or. Ir. Pt.), are ambiguous, as, lying between the part of long series, they illustrate on the one hand a tendency towards valence above *seven*, and on the other hand below *one*.

But none of these kind of ambiguity bears any close relation to chemical inactivity. Hence probably because the idea is *new*, the conception of "salt-like" elements seem to have been over-

looked, and indeed we are almost ready, perhaps, to reject it. It seems peculiarly absurd—a salt-like element! a contradiction of terms! a confusion of ideas? possibly at first, confusion; but later the suggestion may lead to a clarification of ideas and a grasp of new conceptions.

Well then, a class of “salt-like” elements, of definite physical properties, but neutral in chemistry, is a possible common sense anticipation of possibilities.

#### V. THE GAPS IN THE PERIODIC SEQUENCE.

These lacunae in the form of our great chemical sequence are liable to be overlooked. They are two sorts, viz.:

(1) Those within any series, as the gaps between Ca. 40, Sc 44, Ti. 48; but these are not suspicious because the order of valence is II, III, IV, leaving no irregularity, and no extra elements, though the magnitude of the step from 40 to 44, and again from 44 to 48 is rather exceptional.

(2) *The gaps between the series.* These are full of suggestion. The change from a halogen at the end of a series to the alkali leading the next series, is attended usually by a decided qualitative break from a halogen to an alkali, change in nature, (acidiferous, basiferous,) change in normal (?) valence, change, in short, of the most violent kind conceivable.

Hence these gaps between the series exist; but how can argon and helium be considered as candidates to fill the vacancies, without forcing the facts?

#### VI. THE HYPOTHESIS.

Let one arrange the atomic weights in a straight series; then let him mark off the series; then let him write down hypothetical extreme elements for each series; thus, viz.: An Ultra-Fluorine and an Ultra-Sodium—

Li.....F.	U—F	U—Na	Na.....Cl
7	19	19.5	20.5 53 25.4

That is, assuming that the elements were made in series; and that the acid extreme of one series united with the contiguous basic extreme of the next series; or rather—for this might have happened at a time when the conditions for acid and basic properties were not yet established,—let us suppose that the matter, which might have become respectively acid extreme and basic extreme of their series, *united, cutting off the series*, and thus establishing the possibilities for independence and isolation of the series. That is, there may have been at least two kinds of chemical evolution, one *between* the series (resulting in the argonoidal elements); and the other *in* the series, giving us our well known long and short series.

Now, these hypothetical Ultra-Fluorine atoms and Ultra-Sodium atoms might (at least numerically) unite, giving a “something” which would have a molecular weight, theoretically a molecular weight, but which would elude all attempts at separation as an element, and hence would masquerade as an “atomic weight.” (And notice that a scientific candor regards an “atom” not as un-entable—or in-divisible things, but rather as only un-cut—or un-divided.)

Now, such a salt-like element would prove a disturbance in classification at first; it would seem to interfere seriously with K. 39; Ca 40, but only in a Pickwickian sense; for the hypothetical salt-like element would have no “combining weight,” no valence, in short, no external chemistry.

Now, argon would seem to be some sort of a thing like that indicated as possible; just the kind of matter needed to fill the *gaps* of the Periodic Sequence, a salt-like element; salt-like in its inner structure, an element in its opposing all attempt at further practical experimental simplification; and, further, it would be the



anomalous kind of thing that argon is, viz.: Something with apparent identity of "mol. wt." and "at. wt."

And, whatever the truths of all this, it is a startling lesson on the nice distinctions in new definition and new meaning of live scientific terms.

Similarly, a study of the enormous gap between hydrogen, (a part of an incomplete series, apparently—for Pre-Flourine has not yet been picked up) and—lithium, will show the need of at least one salt-like element like argon—perhaps several if the II series suffered a primordial disintegration. Helium apparently comes in the II—Li gap; that is enough to say for the present.

#### VII. THE SPECIFIC HEAT LIMIT, 1.66.

It may be urged against the "salt-like" or double nature of a molecule-atom like that supposed to be characteristic of argon, that the internal energy function must be greater than that implied in the limit 1.66. But notice, as pointed out by Nasini, [*Gazz. Chim. Am. J. Sci.* p. 379, 1895] that while all monatomic molecules should respond to their limit 1.66, yet it does not conversely follow that all molecules showing this figure are really monatomic. Thus the ingredients might have been so nicely adjusted and so firmly united that in vibration they would act together (for *rough heat vibrations*) in exquisite accordance. Thus also the supposed atoms, say of hydrogen, are undoubtedly complex, yet they may vibrate each as an independent unit for rough vibration, while for the finer vibrations suggested by the harmonic relations of spectrum lines, they may show great sub-complexity.

#### VIII. THE POSSIBLE PROOF.

In such a hypothesis as that suggested, the normal mind will neither seek nor accept as proof that which is inappropriate.

The suggestions which we have to offer are of two kinds: the concrete and the abstract.

## A. THE CONCRETE.

There are two lines suggested here, viz.: the (1) spectroscopic, and (2) the other argonoid possibilities.

(1) The spectroscopic behavior of argon is well known. There are two kinds or sorts of spectral lines, viz.: the red, or positive, or cold, and the blue, or negative or hot spectrum; these have some lines in common.

Now, we have no working theory of the relation and meaning of a complete spectrum, beyond such formulae as Balmer's, to develop the rythmical connection of lines in harmonic relation. But it is noticeable that many workers have been frequently impressed with the "doubleness" of relation of the spectral lines of argon.

Now there is no proof here but the indications—whatever their worth—are seemingly in the right direction, provided that the seeming doubleness shall lead to an identification with the two inseparable ingredients of the salt-like argon.

In the case of helium, the explanation is similar but more complicated, its spectrum being a composite of *two sets of three harmonic series each*. (Runge and Paschen.)

(2) **The Predicted Possibilities.** In calculating the other opportunities for argonoid elements, we observe that there are:

H—Li	Gap	Helium $4 \pm$
<sup>1</sup> F— <sup>7</sup> Na	"	Argon $40 \pm$
<sup>19</sup> Cl— <sup>23</sup> K	"	Eka—Argon $74 \pm (=3.65+37.5)$
<sup>35.4</sup> Br— <sup>39</sup> Rb	"	Dwi—Argon $165 + (=81.5+83.5)$
<sup>80</sup> I— <sup>85.5</sup> Cs	"	Tri—Argon $259 \pm (=120+131)$
<sup>127</sup> [Eka. I]—[Eka. Cs]		Gap 4—Argon.
<sup>132</sup> [Dwi. I]—[Dwi. Cs]		Gap 4—Argon.

It is more than hazardous to assert anything dogmatically, but it seems plausible that if other argonoid elements, having similar

physical and chemical properties, and have as "at. wts." respectively, approximately 74, 165, 259, if such should be found later, it would offer some justification to this line of explanation.

#### B. THE ABSTRACT.

It is the tendency of the human mind to frame all of its information in one symmetrical consistent system. I suppose the word philosophy is a synonym for the work and result in the purely mental sphere. We frequently deride these attempts as unscientific, but are they anything more than rashly premature attempts of the human mind to grapple with the problem of the solution of the universe?

Now, how far may a self-respecting student go in this direction. For one, I would frankly confess the mental weakness and discouragement inevitably incident to a temporary confusion of our outlook, when everything seems "at sixes and sevens;" and I would claim the agnostic right to arrange the view of our generalized knowledge so that it may present the aspect of one consistent growing system, if justified by facts.

Then if this speculation may help to show that our chemical system is large enough and elastic enough to admit such orphans as argon and helium to the common household, not to the displacement of other elements, but to their own reserved seats, will the attempt not be justifiable; nay, more, will it not be a positive advance? And an advance in two ways. For, *firstly*, it will give us the temporary encouragement of feeling that our progress thus far is more secure and accordant; and, *secondly*, it will hasten the time when our genetic hypothesis of the elements may be used in its legitimate sphere, viz., as a working hypothesis.

Thus, in a word, argon and helium may be included in the *gaps between* the series; this makes the standing of the Periodic Sequence more secure, and it also calls attention to the significance of the gaps in any hypothesis of the chemical elements.

## MAGNETIC CONCENTRATION APPLIED TO SULPHIDE ORE.

BY G. M. GOUYARD.

Read at Meeting, February 1, 1897.

It is not the intention of the writer to treat in this paper the broad subject of the concentration of ores by magnetic agency, but merely to call the attention of the Society to some peculiar reactions which take place in the magnetic treatment of a particular class of ores under certain conditions.

Experiments in magnetic concentration were made as far back as 1850 by Mr. W. E. Newton, an Englishman, who may well be called the pioneer in this field. Mr. Newton was followed by Mr. F. J. King in 1873, and by Mr. F. J. Bolton in 1877. However, as far as known, these experiments were not productive of practical results.

In 1881 Mr. Ellis Clark, in a paper written for the American Institute of Mining Engineers, gives an interesting description of some work done in the separation of spathic iron ( $\text{FeCO}_3$ ) from zincblende at Pribram in Bohemia. He states that the ore is roasted in small ovens long enough to transform the spathic iron into magnetic oxide by driving off the carbonic acid. These early experiments had for their object the elimination of the iron from the zinc in ores.

In 1873 Mr. J. R. Francis took out a patent for a method of concentration of copper- and iron-pyrites, based on the principle of magnetic concentration, which patent was improved upon by Mr. Francis A. H. La Rue in the following year; but these experiments were more in the form of laboratory tests, and the process was not put into commercial operation.

In the United States much has been done in the field of concentration of iron ores by means of electro-magnetic concentrators. In 1852 Mr. William P. Blake made some magnetic iron concentrates on a somewhat large scale at Crown Point and Moriah on Lake Champlain (A. I. of M. E. Transactions, Plattsburg meeting, June, 1892.) It is, however, only within the last ten or fifteen years that magnetic separation has become a commercial success. Those interested in the details of this subject are referred to the writings of Messrs. Blake, Fowle, Birkinbine, Langdon, Hoffman, and others, who have gone over the field very thoroughly.

The work done by the gentlemen referred to above was confined to the making of iron concentrates, and in the paper tonight the magnetic concentration of sulphide ores containing iron, zinc, lead, and silica will alone be considered.

These ores are very common, specially in the West, and those carrying small amounts of the precious metals are practically valueless on account of the large excess of zinc, which renders them hard to treat. In Leadville, for instance, there are hundreds of thousands of tons of these ores which are, so to speak, abandoned. They carry about 35 per cent. sulphur, 10 ounces silver, 12 per cent. lead, 22 per cent. zinc, and 18 per cent. iron. Water concentration has been tried and was found to answer fairly well when the ores were comparatively rich in silver and lead, but the lower grades, such as shown in the above analysis, proved very difficult to concentrate in this way. The mixture of iron, lead, and zinc minerals, and the slight difference between the specific weights of the zinc and iron, made it very slow work to separate one from the other, or else the loss in the tailings was too great. Many experiments were made and much time was spent in seeking an economical way to obtain a high concentration, regardless of time, or to save time at the expense of the values of the iron and lead lost in the tailings. However, the experience of one mill after another has been, that neither method was profitable, and, consequently, the several mills which were started, were afterwards shut down.

About this time some experiments were made on these ores by roasting to a magnetic sulphide, and endeavoring to separate their component parts by magnetism. The writer made experiments in that line himself but soon discovered that although a pretty thorough separation could be effected as far as the iron was concerned, still a non-magnetic product was left over which had to be treated afterwards by wet concentration, and as the product thus obtained ran high in sulphur it was not very desirable for smelting. These experiments were then conducted on a different line. The ore was roasted down to 5 or 7 per cent. sulphur, at which point most of the iron is reduced to a sesquioxide and consequently is non-magnetic. The sesquioxide is afterwards reduced to magnetic oxide ( $\text{Fe}_3\text{O}_4$ ) by mixing the roasted product with finely divided coal at the last stage of the operation and when the ore is still cherry red. It was at this point in these experiments that a very curious discovery was made. When the ores are roasted to a point where the iron present is in the form of a complex sulphide ( $\text{Fe}_x\text{S}_y$ ) the magnetic product will be found to run high in iron and low in lead and zinc. A number of experiments made to bring out this feature gave practically the same result. In no case did the lead in the magnetic portion exceed the zinc, and it is probable that both metals were carried mechanically into the magnetic product. But, after a roasting process, in which the iron contents of the ore are transformed into a sesquioxide, if then the latter is reduced to magnetic oxide in presence of a reducing atmosphere, the magnetic product will be found invariably to carry a heavy percentage of lead. The zinc percentage remains the same in the magnetic oxide as in the magnetic sulphide product, consequently it must be inferred that when the ferric oxide is converted into magnetic oxide the lead is subjected to some law of mechanical attraction or chemical affinity, not well understood, by which it attaches itself to the iron. For reasons which it is not necessary to go into at present these experiments were interrupted, and, consequently, the chemical condition of the lead and the reasons for this strange result have not

been thoroughly investigated as yet. The following figures will, however, explain more clearly the results obtained. These runs were made in ton lots and the figures in the weight column are the actual weights of the samples operated upon.

*Experiment A.*

	Weights lbs.	S per cent.	Ag oz.	Pb per cent.	SiO <sub>2</sub> per cent.	Fe per cent.	Zn per cent.
Original ore.....	2000	24.0	10.0	24.7	5.0	15.2	21.0
Roasted product.....	1846	14.7	10.5	27.5	5.4	16.4	22.0
Magnetic product.....	461	11.8	9.4	16.5	5.0	35.2	8.4
Non-magnetic product.....	1385	18.0	10.8	31.0	5.7	9.4	26.2

*Experiment B.*

	Weights lbs.	S per cent.	Ag oz.	Pb per cent.	SiO <sub>2</sub> per cent.	Fe per cent.	Zn per cent.
Original ore.....	2000	23.7	10.0	25.0	5.0	15.4	21.6
Roasted product.....	1784	7.8	10.6	27.7	6.4	16.6	19.3
Magnetic product.....	785	3.4	8.7	27.1	6.4	29.4	8.2
Non-magnetic product.....	999	11.5	12.0	29.0	6.2	7.6	28.3

*Experiment C.*

	Weights lbs.	S per cent.	Ag oz.	Pb per cent.	SiO <sub>2</sub> per cent.	Fe per cent.	Zn per cent.
Original ore.....	1500	23.7	10.0	25.0	5.0	15.4	21.6
Iron concentrates.....	500	46.3	2.5	0.0	6.4	40.1	2.8
Total mixture.....	2000	31.3	8.0	18.0	6.2	21.2	15.0
Roasted mixture.....	1630	6.7	9.5	20.5	6.5	23.6	15.9
Magnetic product.....	1174	2.8	9.6	21.7	5.0	31.4	9.0
Non-magnetic product.....	456	10.4	10.5	21.2	8.0	8.2	34.5

From these three runs it is apparent that the percentage of lead varies considerably in the magnetic products. In run A the ore was roasted down to 14.7 per cent. of sulphur, and the lead carried into the magnetic product was 15 per cent. of that in the original ore. In run B the ore was roasted further, and the magnetic product carried 40 per cent. of the lead in the original ore. In the run C 500 pounds of iron concentrates were mixed with the original ore in order to raise the percentage of iron in the material treated, for the purpose of ascertaining whether the tendency of the lead to go into the magnetic product would be augmented by

increasing the ratio of iron to the other metals present. The assay shows that the concentrates used carried no lead, and yet the magnetic product carried 70 per cent. of all the lead in the mixture! A number of other experiments were made but only these three examples are given as they were carried out on the same class of ore, and under the same conditions and therefore bring out the mutual attraction of lead and iron under the conditions specified, more clearly than if the reactions were complicated by the introduction of other features.

The experiments were also made to determine the effect of high heat upon the amount of lead carried into the magnetic product.

*Experiment D.*

	Weights lbs.	S per cent.	Ag oz.	Pb per cent.	SiO <sub>2</sub> per cent.	Fe per cent.	Zn per cent.
Original ore.....	125	not determ.	4.8	4.2	7.2	23.0	16.5
Roasted product.....	100	" "	6.3	1.0	8.0	31.8	19.0
Magnetic product.....	97	" "	6.2	0.6	6.6	32.0	19.6
Non-magnetic product.....	3	" "	5.3	1.0	8.2	22.0	32.0

*Experiment E.*

	Weights lbs.	S per cent.	Ag oz.	Pb per cent.	SiO <sub>2</sub> per cent.	Fe per cent.	Zn per cent.
Original ore.....	122	not determ.	4.8	4.2	7.2	23.0	16.5
Roasted produce.....	100	" "	6.5	4.8	8.0	27.8	21.0
Magnetic product.....	60	5.2	6.5	6.5	8.0	38.4	10.0
Non-magnetic product.....	40	not determ.	6.5	2.6	8.0	12.0	33.5

In experiment D the heat was great enough to partially volatilize the lead and fuse it on to the iron and zinc, thereby forming cinders. The magnetic product in that case was 97 per cent. of the weight of the roasted material, and carried with it most of the zinc in the ore. In experiment E, where the ordinary conditions of roasting were carried out, most of the lead in the roasted material—in fact 81 per cent. of it—was carried into the magnetic product with the iron. These experiments prove that high heat has very little to do with the precipitation of the lead



on the iron, especially as these experiments were repeated a number of times with the same results. The phenomenon may possibly be due to some electrical action taking place between the iron, zinc and lead present at a certain stage of the reducing process, similar perhaps to the well known results obtained in dry batteries composed of copper and zinc.

The *modus operandi* in conducting these experiments is simple, in fact they can be carried out with reasonable accuracy in an assay furnace using a small roasting dish. One should not lose sight of the fact, however, that discrepancies in small weights often cause large errors when converted into ton lots. Better results are always obtained in large lots of two to four tons at the time. The ore should be crushed to about  $\frac{1}{4}$ -inch mesh or a little finer, and roasted until the white fumes of sulphur have disappeared. Then the pulp should be mixed with from 3 to 5 per cent. of its weight of fine coal and stirred, roasting dish being kept covered. After four or five minutes the roasted product should be allowed to cool without being exposed to the air, as in that case it would combine with the oxygen of the air and turn again to a sesquioxide. When the product is cooled it should be crushed to 20 mesh, and separated with a hand magnet.

In roasting on a small scale one should be careful to use as large a roasting dish as possible on account of the decrepitation which takes place, which in this class of ore is very considerable. The particles of ore are disintegrated by the heat, and unless the dish is covered, fly all over the muffle. In practice decrepitation saves a good deal of crushing, for by actual experiment it has been found that with ore crushed to  $\frac{1}{4}$  mesh all but 30 to 35 per cent. of the roasted product will pass through a 20 mesh sieve, and therefore only this small amount had to be returned to the rolls.

In the experiments mentioned above an electro-magnetic separator was used which had a capacity of 800 pounds of roasted material per hour. This machine was designed specially for this work, and it combined the best points of those already on the

market, with a few devices added to make it entirely automatic. It needed no attention at any time, except oiling the few bearings a couple of times a day. In the near future a description of the machine may be given as it may interest some of our members. It should also be stated before closing that some very successful experiments in the bricking of the magnetic product have been made, and that this can be done at a small cost.

It is to be hoped that the facts given above may lead to a further investigation of this important subject and that any conclusions reached as to this singular action of lead, or with regard to its condition in the magnetic product, may be laid before the Society.

These experiments were made as early as 1890 and 1891, and have not, up to this time, been published.

#### DISCUSSION.

**W. L. Austin, Denver.**—The main difficulty arising in the magnetic concentration of ores is to break up the material to be treated so that only magnetic and non-magnetic substances are to be handled. The various mineralogical components are often so intimately mixed that it becomes very difficult, or economically impracticable, to sufficiently separate them by any reasonable amount of comminution so as to effect a subsequent magnetic separation of commercial value. This is the case with some of the zincky ores of Leadville where the mixture of the sulphide minerals is exceedingly intimate.

It is a self-evident proposition that the finer the comminution of the ore, the thinner the layer of crushed material passing through the magnetic field, or the oftener it is acted upon by magnetic influences, the better will be the results obtained; but the texture of the ore itself, the way it breaks when crushed, the tenacity of its adhesion to the gangue, and the degree of its magnetic quality, are all important factors to be considered. Also the effect of temperature, and of other physical and chemical conditions, upon the material subjected to magnetic treatment, should not be lost sight of.

The Society is indebted to Mr. Gouyard for laying before it the result of his experiments. The fact so clearly brought out in the tables submitted, that under certain conditions a large proportion of the lead contents of zincky ores (in experiment C over 70 per cent.) is carried over with the iron when the whole is brought under the influence of the magnet, has not to my knowledge been made public before. The economic value of this discovery would appear to be considerable, for by the help of the magnetic separator it ought to be possible to produce, at slight cost, a desirable smelting product from ores which at present have little or no market value.

From a scientific point of view, it is interesting to note that lead, usually considered as diamagnetic, is drawn over into the magnetic product. It is known, of course, that two diamagnetic bodies may form a magnetic compound (for instance copper and bromine) but it is certain that in the case under consideration the lead enters into a new combination with any other element present, and unless it attaches itself to the iron compounds in some hitherto unsuspected manner the phenomenon is difficult of explanation.

In connection with the concentration of minerals by taking advantage of their paramagnetism under certain conditions, the work done by Messrs. Wilkens and Nitze is of much importance. These experimenters have shown that by subjecting the infinitesimal magnetic permeability of such minerals as hematite, limonite, siderite, garnet, pyrolusite, monazite, and many others, to a peculiarly high magnetic power, a direct magnetic concentration (without preliminary roasting) can be effected, and that by varying the power used, a further separation of the component parts of the magnetic product may be brought about. The amount of amperage necessary for producing the extremely high field is comparatively small. As is well known, the magnetism of a mineral does not necessarily depend upon the amount of its iron contents, for iron pyrites is not attracted by the magnet, even in the Wetherill separator.

**M. Ruthenburg, Denver.**—Mr. Gouyard's remarks suggest the following explanation of the peculiar action of the lead in his plan of magnetic concentration. The addition of carbonaceous matter in the form of fine coal, after the completion of the roast and in the presence of iron in various degrees of oxidation, reduces the lead to the metallic state, but only at the point of absolute contact between the metallic substances named. The reduction which takes place causes the metals to adhere, and the iron having become magnetic pulls the lead with it. The fact that in one of his experiments the addition of more iron increased his lead saving nearly fifty per cent. confirms me still more strongly in this view.

Another feature of his experiments is that his results are almost identical with those obtained by wet concentration on tables, and it is also worthy of note that the silver contents remain practically the same in the heads and tails. This latter is also the case when this class of ore is subjected to wet concentration.

Magnetic conditions in the concentrating machine have a great influence upon the quality of work done, and the adjustment of the polar relations—as well as of the current strength—should be made to a nicety to suit the material being treated.

It is possible by means of an alternating current to apply magnetic concentration to materials considered as practically free from magnetic influence. The action is due to induced secondary currents in the grains of ore themselves, causing them to act as though they were magnetic.

**Henry A. Vezin, Denver.**—Mr. Austin suggests that crushing to the necessary degree of fineness may, in some ores, such as the sulphides of Leadville, cost so much as to seriously detract from the value of this method of treatment. I think that frequently this expense is over estimated and fine crushing is condemned without an actual determination of how much it costs.

Rittinger determines the amount of duty or foot pounds of work performed in crushing, by assuming that this work is in proportion to the new surface formed by the splitting or crushing.

For the sake of simplicity he takes a cube of rock of perfectly uniform nature; having a length of side  $l$ , and assumes that it requires  $d$  foot pounds to divide it parallel to any one of its faces. If the three edges that are at right angles to each other are successively divided into  $2, 3, 4 \dots n, \dots m$  equal parts, and the cube is divided by planes parallel to the three faces, and passing through the points of division, we obtain:

8 cubes with a length of side  $\frac{1}{2} l$  with  $3 \times 1 \times d$  foot pounds.  
 27 " " " " "  $\frac{1}{3} l$  "  $3 \times 2 \times d$  " "  
 64 " " " " "  $\frac{1}{4} l$  "  $3 \times 3 \times d$  " "

$n^3$  " " " " "  $\frac{1}{n} l$  "  $3(n-1) \times d$  " "  
 $m^3$  " " " " "  $\frac{1}{m} l$  "  $3(m-1) \times d$  " "

The greater the number of divisions the greater the amount of power required. Let  $D_n$  and  $D_m$  represent the number of foot-pounds required to divide two cubes of the same size and nature to cubes of respectively  $\frac{1}{n}$  or  $\frac{1}{m}$  the original size, then:

$$\frac{D_n}{D_m} = \frac{3(n-1)d}{3(m-1)d} = \frac{n-1}{m-1}$$

If  $n$  and  $m$  are great compared to 1, the latter may be neglected. Then

$$\frac{D_n}{D_m} = \frac{n}{m} = \frac{1}{\frac{1}{n}}$$

That is to say: the power required is in nearly direct ratio as the degree of fineness, or inversely as the sizes of the crushed rock. Thus: if of two one inch cubes one is reduced into cubes of  $\frac{1}{2}$  inch, the other of  $\frac{1}{4}$  inch, the crushing in the second case will require about four times as much power as in the first.

In actual crushing the rock cannot be divided in this way. The fragments are of various shapes and of every size from the coarsest to infinitesimally fine. The duty required to crush will be in proportion to the degree of fineness represented by the average

size of all the pieces. This differs according to the kind of crushing machinery used. With crushers and rolls the average will be the mean between the largest size and the finest, or even greater. With stamps it may be  $\frac{1}{3}$  to  $\frac{1}{4}$  of this mean, so that the cost of crushing with the latter would be 3 to 4 times as great as crushing to the same maximum size with the former. Mr. Theodore A. Blake reported, some years ago, that he increased the capacity of a Chilian mill to three times what it had been, by making the runners narrower, and increasing the radius of the path so that the grinding action was decreased. He also provided a free discharge, and screened the stuff outside, returning the raff to the mill. The discharge in the old mill was similar to that of a stamp mill being effected by the swash, many of the particles that were fine enough, not being discharged but remaining in the mill and being ground finer. As the screens in both cases were the same, 30 mesh, the average size of the ore ground in the old mill, must have been about  $\frac{1}{3}$  as great as when ground in the new one.

Besides the size to which stuff is to be crushed, the specific gravity and the hardness govern the cost. The capacity of a machine is governed by the bulk of the ore. Other things being equal, a crusher or a pair of rolls will crush twice as many tons of iron pyrites or zinc blende as of quartz, so that, if quartz were no harder than the others, it would require twice as much power. But it is three times as hard as pyrites, so that it would require six times as much power to crush a ton of quartz as a ton of iron pyrites to the same fineness. Assuming that it costs for power and wear and tear, oil, etc., \$1.00 per ton to crush quartz with crushers and rolls to pass 20 mesh ( $\frac{1}{8}$  inch in diameter) or to an average diameter of  $\frac{1}{16}$  inch, it would cost but  $1\frac{1}{3}^c = 16\frac{2}{3}$  cent to crush pyrites or zinc blende to the same size. As pure galena is three times as heavy as quartz, and  $\frac{1}{2}$  as hard, the cost of crushing it to 20 mesh would be

$$\frac{100}{3 \times 6} = 5.5 \text{ cents per ton.}$$

If the quartz is to be crushed to pass a 10 mesh screen, the diameter of the holes being  $\frac{1}{16}$  inch, and the average size  $\frac{1}{16}$  inch, the cost per ton would be \$0.50, and the cost per ton for crushing pyrites and galena, 8.3 cents and 2.75 per ton, respectively. The cost of labor in tramming the ore and feeding the crusher would, of course, be the same per ton no matter what the kind of ore.

## CRATER LAKE, OREGON.

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By H. B. PATTON.

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Meeting of March 1, 1897.

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This lake is situated about a hundred miles north of the California boundary line, and seventy-five miles east of Medford, the nearest railway station in the Rogue River Valley. It is reached by taking the train to Medford, or Ashland, and then by wagon road, the road continuing right up to the rim of the crater. This road is partly a government road, and while the latter portion is rough and steep, traveling is fairly comfortable for a mountain road. The distance from Medford is about seventy-five miles, from Ashland ninety-five miles.

Few maps show the location of this lake, its existence having been scarcely known up to about ten years ago. The United States Geological Survey published a special Crater Lake map which has a brief printed description of the lake and its geology on the back. This may be purchased for five cents.

The crater is situated in a well timbered (mainly hemlock) region, about twenty-five miles from the Klamath Lakes. It is a characteristically volcanic region, abounding in basalts, andesites, rhyolites, and tufas of the same. The rim of the crater is 8,000 feet above the level of the sea, the surface of the lake being about 6,000 feet, and the bottom of the lake 4,000 feet above the same level. The bottom of the lake is 100 to 200 feet below the level of the great Klamath Marshes, on the east base of the Cascade range. The crater itself lies in the midst of a mountain recently christened Mt. Mazama, which rises about 2,000 feet above the level of the Cascade plateau.



It is a strikingly beautiful and impressive sheet of water, being completely surrounded by almost perpendicular walls from 1,000 to 2,000 feet high. The color of the water is an intense ultramarine, more brilliant and of a deeper shade than the renowned blue of the Mediterranean. The surface temperature at mid-day in the last half of August was found to be 60° F., falling to less than 40° F. as a depth of several hundred feet is gained, the temperature again rising to 46 or 48 in the lower depth. While the lake abounds in the lower forms of life it is absolutely devoid of fish of any kind.

One peculiar and surprising feature is the difficulty experienced (owing to the customary absence of ripples on the surface), in focussing the eye upon the surface of the water lying so deep below, a boat floating on the lake appearing to be suspended in space. The tourist with difficulty appreciates the great size of this sheet of water which is from five to six miles in diameter, nor does he at first realize the great height of the walls of the crater which rise abruptly 2,000 feet above the surface of the lake. The shore of the lake is quite inaccessible except at a very few points, and even there the climb is exceedingly steep.

Wizard Island is a small volcanic cone rising out of the lake to a height of 800 feet, with a beautiful hopper-shaped crater on the summit. It is about a quarter of a mile from rim to rim of the crater, and the island is itself about a mile in diameter.

Altogether this wonderful lake presents one of the most remarkable natural phenomena in North America, and would well repay a journey across the continent.

#### DISCUSSION.

A discussion ensued relative to the causes which led to the disappearance of the upper part of the mountain which is now only represented by the crater. Professor Patton stated, that, according to the opinions of the experts on the U. S. Geological Survey, the disappearance was due to the subsidence of the summit into the crater. The evidence in favor of this view was in part, that there

are no large blocks of rock scattered around the adjoining country, such as would presumably be present if an explosion had taken place; and, secondly, a flow of lava had apparently been stopped in the act of flowing over the present edge of the crater, the last portions of said flow having trickled back into the crater.

Dr. Austin suggested that this might be a parallel case to that of Mount Bandasan in Japan, where several thousand feet of the mountain had in recent times been blown off, covering villages some 50 feet deep in ashes and spreading debris over a large extent of territory.

Mr. R. C. Hills cited Trapper's Lake in Colorado as another example of a crater lake, evidently of volcanic origin, being surrounded by lava flows. Like Crater Lake in Oregon, its sides are very steep, and about 2,000 feet high. The lake is of great depth, one mile long by a mile and a half wide, the water being of a deep emerald-green color, due probably, as in the case of Crater Lake, to its great depth and purity.

Professor Patton, referring to his previous paper on spherulites, stated, that he was preparing a short paper treating on the subject. He made some additional remarks on this topic, illustrating them by a fine collection of specimens of all sizes, from that of a marble up to that of a man's head. This paper will be shortly printed in full.

## THE OSCURO MOUNTAIN METEORITE.

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By R. C. HILLS.

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Meeting of April 3, 1897.

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The Oscuro Mountain meteorite, here described, is the third independent occurrence of the kind recently announced from south central New Mexico.

The first, which is known as the El Capitan meteorite, was discovered in 1893 on the north slope of El Capitan Mountains and subsequently described by E. E. Howell.\* It is supposed to have fallen in 1882.

The second, which is known as the Sacramento Mountain meteorite, is supposed to have fallen in 1876 on the eastern slope of the Sacramento Mountains and was described about three months ago by Warren M. Foote.†

The Oscurion was discovered near the eastern base of the Oscuro Mountains, a north and a south range lying about 40 miles west of the Sacramento range and parallel with it. Nothing is known as to the date of the fall, though the fresh, lively appearance of the surfaces does not suggest a great lapse of time.

For the first intimation of its existence I am indebted to Mr. H. A. Gross, superintendent of the New Mexico Development Company, who, suspecting its true character, succeeded in securing a small piece which he submitted to me while on a professional trip into that country about a year ago. An effort was then made to obtain possession of the balance of the find and Mr. P. Nicol,

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\*American Journal of Science, Vol. I, pp 253-254, 1895.

†American Journal of Science, Vol III, pp 65-66, 1897.

an intelligent employee of the company, was instructed to proceed to Three Rivers and if possible negotiate for the remainder. In this he was finally successful.

Owing to pressing engagements I could not personally investigate the history of the find and requested Mr. Gross to do so. As I have been intimate with him for many years I have the utmost confidence in the results of his careful inquiry into the matter. Writing under date of July 23, 1896, he says:

"The discovery was made by Phillippe Montoya, a Mexican sheepherder living at Three Rivers, Lincoln County, N. M., on or about Dec. 10, 1895. It consisted of three irregular shaped pieces weighing about  $3\frac{1}{2}$ ,  $3\frac{3}{4}$  and  $1\frac{1}{4}$  pounds, respectively, the small piece having been subsequently cut in two and somewhat damaged.

"The locality where it was found is in the eastern foothills of the Oscura Mountains, in Socoro County, N. M., at a point on the south side of a small conical hill composed of gypsum and limestone. This hill is readily distinguishable from others in the vicinity in that it has a considerably broken up limestone cap, about 150 feet across and nearly round and flat on the top. It lies about two and one-half miles west of the Lincoln County *malapais* and about ten miles due west from the "bar W" ranch of the Carrizosa Cattle Co. The hill is also somewhat marked by considerable shallow digging, and prospecting done by the finder in search for more of the material which he supposed was native silver.

"The pieces were found on the south hill-side about two feet, three feet and five and one-half feet apart in a straight line and in nearly an east and west direction—the largest piece being below and the smallest piece above and about twenty feet down from the top of the hill. In conjunction with Mr. P. Nicol, who was with me and had been there before with the finder, I looked very closely around in the vicinity for any more, but was unable to find anything that might have any relation to the meteorite.

"The first piece was obtained by me on December 15, 1895. On March 27, 1896, Mr. Nicol secured the two large complete specimens from Phillippe Montoya himself. About May 1, 1896, Mr. Nicol got the remaining piece. I consider we have it all, as represented by the Mexican who was strongly tempted for any more he might find. Neither of the small pieces have been in possession of more than the second person before we got them and Montoya says we have all he found of it."\*

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\*The Lincoln Co. "malapais" referred to by Mr. Gross is a body of scoriaceous, basaltic lava occupying the lowest portion of Tulerosa Valley for a distance of about 40 miles. It was poured out, at a comparatively recent period, from a vent situated well toward the northern extremity of the valley.

The several pieces weigh approximately as follows:

No. 1, 1,167 grams; No. 2, 1,226 grams; No. 3, 676 grams. The first two are practically intact, except the small portion removed for analysis. The third is in two fragments, of which the larger shows chisel marks and a coarsely crystalline surface of fracture; while the smaller shows chisel and vise marks and has evidently been heated, presumable in a forge. As the two fragments do not fit together there can be no doubt that some portion is missing, and it is probable that the heating was resorted to in order to facilitate the cutting off of small pieces for the purpose of *cruda* experiment intended to reveal the nature of the substance. The quantity of the material thus sacrificed can hardly be conjectured. If the mass was separated, in the first place, into two nearly equal portions and what was thought to be the smaller was subjected to further subdivision, which seems probable, as much as 200 grams may have been destroyed or rendered worthless.

The form and general appearance, as well as the prominence of the "thumb mark," are well shown in the accompanying



Oscuro Mountain Meteorite  
Printed direct from etched slice.

photo-etchings of the two specimens. The surfaces exhibit no evidence of weathering and the thin, dark-brown crust appears to be intact, except that in the depressions, where it is somewhat thicker than on the protuberances, minute cracks are discernable with a lens. A reproduction of the etched figures, printed direct



Oscuro Mountain Meteorite. Mass No. 1, three-quarter size.



Oseuro Mountain Meteorite. Mass No. 2, three-quarter size.

## A RECENT ASSAY BALANCE.

BY L. S. AUSTIN, PH.B., DENVER, COLORADO.

Meeting of April 3, 1897.

With the attention which has been given of late years to gold mining, has arisen a need for a balance at once accurate and quick working. In Colorado especially has it become the custom to perform large quantities of work by scorification in large muffles. As a consequence many weighings have to be made, and because of the small amounts used (½ A. T.) these weighings must be quite exact. Hence unusual requirements, both for speed and for accuracy. The amounts which have to be weighed are frequently—I might say, generally—quite small, and in case of gold, should be reliably weighed to the 10th of a milligram at least.

In the earlier history of mining in Colorado the reduction works did not pay for less than 0.25 ounce of gold per ton. Later the limit was fixed at 0.10 ounce, but of late ores in excess of 0.05 ounce and even less have their gold paid for. Hence the increasing need for reliable results.

This balance, presented for your consideration to-night, is one whose manufacture has been recently begun in this city by Messrs. Smith & Thompson, and whose design involves novel features to which I particularly desire to call your attention.

The beam of the balance is perhaps its most striking feature, it having been trussed for stiffness. It has, in common with other beams, the triangular form of the arms, which brings the upper member in tension the lower in compression. This form has been emphasized in other beams, and particularly on the Sartorius, where the depth of the beam is great in comparison to its length.



This feature has not been carried to such an extent in the assay balance. In the balance before us, with a length of 8 inches we have a depth of beam of 0.65 inches. It is divided into six panels, and the strains may be analytically traced from panel to panel until they reach the center. Certainly the model beam presented here to-night shows a satisfactory stiffness.

The top of the beam has been left quite clear for the transfer of the two riders, each operated from its own end of the beam. It is a question among assayers whether there be an advantage in having a rider on the left side of the beam. It is conceivable that it might slip from its proper position after adjustment. The operator, who has brushed off the pans, and then completed adjustment by means of the spurred nuts provided for that purpose, can so readily accomplish it, that the adjusting rider seems unneeded.

To the question whether a change of form results from the lower member of the beam being longer than the upper as the result of its triangular form, let us take the case of the triangle *fec*., Fig A. Let

$a$  = the coefficient of expansion

$t = T_2 - T_1$  = the increment of temperature

$fc_1 = L(1 + at)$

$fe_1 = \sqrt{H^2 + L^2}(1 + at)$

$ce^1 = H(1 + at)$

Now for an unchanged form we would have,

$L : \sqrt{H^2 + L^2} :: L(1 + at) : \sqrt{H^2 + L^2}(1 + at)$

And canceling out the common factor  $(1 + at)$  we have

$L : \sqrt{H^2 + L^2} :: L : \sqrt{H^2 + L^2}$ .

And in the same way it can be shown that  $fc : fe^1 : ce : ce^1$ .

This is a particular statement of the theorem:—Mutually equiangular triangles have there corresponding sides proportional and conversely.

We, therefore, conclude that variations of temperature affecting all parts of the beam alike can cause no change of form in it,

consequently cannot change the distance from the axis of motion to the center of gravity.

The graduations on the beam are first engine-divided, the beam is then cut, and the pan supports exactly located under the terminal graduations. The method of adjusting the beam is peculiar. The center knife edges are mounted on a transverse spindle, (Figs. 3, 4, 5 and 8), and this spindle is carried in a suitable bearing in which it can revolve slightly. The movement is actuated and controlled by two set screws which also carry the spurred adjusting nuts, and which bear upon a pin fixed at the top of the spindle as shown at Figs. 5 and 6. To bring the arms to the same length, the balance is adjusted unloaded, and then a 2-gram weight is placed in each pan. The center spindle is now revolved as required, thus changing the position of the knife edges until a balance is obtained. When the edges are so set that the balance is perfect, both loaded and empty, it can be assumed that the arms are of equal length.

Calling  $l$  the half length of the balance,  $p$  an increment of weight which will give a visible deflection,  $W$  the weight of beam and pans,  $x$  the distance of the axis of motion from the true central vertical plane

$$Wx = pl \text{ and } x = \frac{pl}{W}$$

With an adjustment to  $\frac{1}{100}$  milligram, which can easily be seen, the length of the beam being 8 inches and its total weight 6950 milligrams we have:

$$x = \frac{0.01 \times 4}{6950} = 0.00000575 \text{ or say } \pm \frac{6}{1,000,000} \text{ inches,}$$

which represents the probable error in the setting of the knife edges from the true position.

In the Troemner and Oertling balances, so in this, the end bearings or screws are tipped with stone, except that in place of the

usual agate, these tips are of the harder sapphire. The hardness of agate=7, that of sapphire=9, the latter "being exceedingly tough when compact"\*.

It is interesting to note that in constructing the balance the bearings are brought to the same plane by means of a surface plate. The adjustment can, I find, be brought to within a probable error of  $\pm 0.000125$  in the case of this particular maker.

The frame which raises the beam from its bearings is, as in other balances, raised by a cam. By removing one of the levelling bubbles an adjusting screw can be got at by which the lift of the beam from its knife edges can be brought to a very small amount, just enough in fact to ensure centering the beam. Thus arises an advantage, much appreciated by assayers who have tried it, that there is no "kick" to the balance, and the direction of movement of the pointer at once indicates how to move the rider.

The following table gives data of some balances which may be useful for purposes of comparison:

	Length of Beam.	Weight of Beam.	Weight of Pans&c	Weight. Total.
Becker & Sons, pulp balance.....	71 $\frac{1}{2}$ "	39.15	67.80	106.95
Wm. Ainsworth, pulp balance.....	93 $\frac{1}{4}$ "	69.80	56.25	126.05
Becker & Sons, button balance (solid beam)...	9"	23.70	6.00	29.70
Becker & Sons, button balance (open beam)...	9"	33.95	10.10	44.05
Henry Troemmer, gold balance (open beam) ..	10"	8.70	3.80	12.50
Smith & Thompson gold balance (open beam)	8"	4.65	2.30	6.95

**Sensibility of the Balance.**—With the balance in adjustment, if we add a small weight  $p$  to one of the pans, it will cause a deflection  $\theta$ . Let  $l$  be the half length of the beam,  $W$ =weight of beam, pans and load,  $r$ =the distance from the axis of motion to center of gravity, then  $p \times l \cos \theta = W \times r \sin \theta$

$$\frac{\sin \theta}{\cos \theta} = \tan \theta = \frac{pl}{Wr} \text{ or:—}$$

\*Dana.

†Stewart and Gee's Physics, p. 64.

The sensibility is increased by increasing the length of the beam.

The sensibility is increased by diminishing  $W$ , the weight of the pans, beam and load.

The sensibility is increased by diminishing the distance of the center of gravity from the axis of motion.

On the contrary, the stability and the quickness of motion increases with the distance of the center of gravity from the axis of motion.

In the above equation we get  $r = \frac{pl}{W \tan \theta}$

For our balance we have found  $p = 0.2$  milligram,  $l = 4$ ,  $W = 6950$  milligrams, and tangent  $\theta = 0.0225$ . Hence

$$r = \frac{0.2 \times 4}{6950 \times 0.0225} = 0.0051,$$

a quantity which ensures a satisfactory quickness of vibration. (a double vibration occurring in ten seconds), which is quite noticeable to the experienced eye.

There is, however, another point affecting sensibility, vaguely called friction, which may be considered to advantage. In certain balances, as in the one under discussion, the stone bearing surfaces on which rest the knife edges are rounded so as to carry those edges at their middle points, as shown in figure C magnified, and in Figs. 5 and 6.

$F^3$  is the pin by which the spindle is adjusted,  $F$  is the spindle carrying the knife edges  $F^1 F^1$ .

Let us now pass two planes through the bearings perpendicular to the spindle. In each plane, ( $x, x$ , Fig. C), as will be shown later, each knife edge has two bearing points whose distance apart is represented by  $l'$  Fig C. At whichever knife edge the distance  $l'$  is the greater is the one to be taken for this discussion.

$$\text{Then } \frac{Wl'}{2} = pl \text{ and } l' = \frac{2pl}{W}$$

Where  $W$  = total weight of beam and pans,  $l$  = half length

of beam,  $p$  = a small increment to be added to one pan to just produce a small, sensible, initial deflection.

This quantity, for this balance, is approximately 0.002 milligram. Now,  $l = 4'$  and  $W = 6950$  milligrams, hence,

$$l' = \frac{2 \times 0.002 \times 4}{6950} 0.0000023$$

or about  $\frac{1}{430000}$  inch. Were the other knife edge but a single mathematical point then  $l'$  would =  $\frac{1}{430000}$  inch.

Let us now consider what would happen were  $l'$  to become zero, that is, if each edge were to rest on a single mathematical point.

$$\text{As before } p = \frac{Wl'}{2l} \text{ and with } l' = 0, p \text{ also} = 0;$$

that is, the balance would be for initial deflection infinitely sensitive, or the slightest breath of air would produce movement. As we know this is not the case, we conclude that the knife edges have sensible width. These movements would be very small, since any appreciable deflection is opposed by gravity according to the

$$\text{equation } \tan \theta = \frac{pl}{Wr}$$

In Fig. B, it has been attempted to show graphically these resistances to motion. It indicates that for deflections less than 0.78 seconds of arc = tangent 0.000225, the resistance due to gravity is less than that due to friction, or that initial movement is first resisted by friction, after which gravity becomes the chief opposing force.

One realizes what is the sensibility of a fine assay balance when the effect produced upon it by an incandescent light is observed. The heat radiated from the globe, whose intensity is greater than that of an ordinary oil lamp, visibly affects the adjustment of a balance. Consequently such lights should be suspended over the center of the balance so as to affect both arms alike. I have estimated that the center of gravity of either arm of the beam with its pan is at a distance of 3 inches approximately from the axis of

Fig. A.

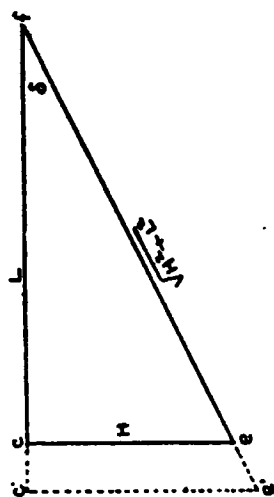
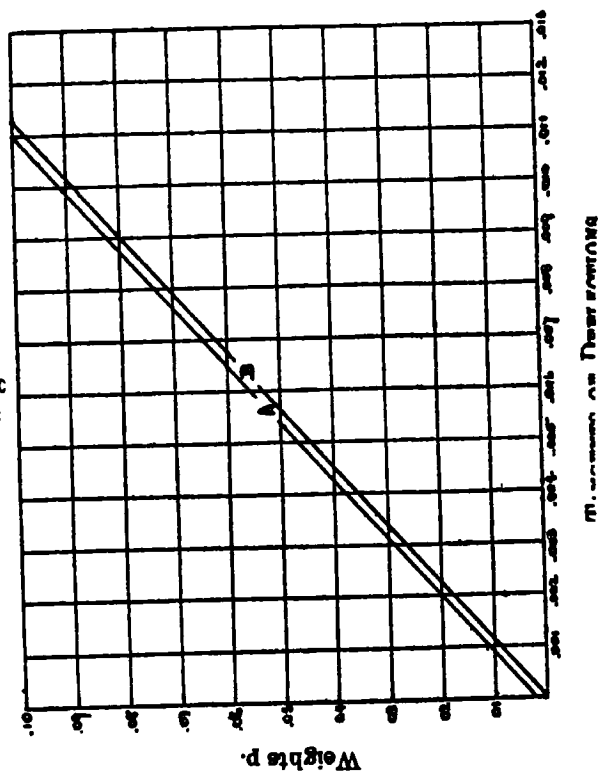


Fig. B.



## THE PELICAN MINE, CLEAR CREEK COUNTY, COLORADO.

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BY B. B. LAWRENCE.

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Meeting of May 1, 1897.

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Mr. Lawrence narrated in an exceedingly interesting manner the early history of the mine, bringing in personal recollections and anecdotes which made the time pass very rapidly.

Maps showing the workings of the mine at different stages of its development, and a number of interesting documents—among which were patents dated back to 1872, one signed by President Grant—were exhibited. Also specimens of ore, country rock, porphyry dike, etc., were shown, and Mr. Lawrence's clear exposition of the difficulties encountered in first finding ore, and keeping out of litigation, demonstrated the well-known fact that a mining engineer must be a good deal more than an abstract scientist.

The following is a brief resumé of the paper:

The first authentic discovery of silver ore in Colorado seems to have been in the vicinity of Georgetown in 1864. Ex-Governor Steele, who was then the Territorial Executive, prospected McClellan Mountain about that time and located the "Belmont" claim.

The "Pelican" mine was discovered in 1868, and located by Messrs. Streeter and McNiff. The law of 1866, under which these locations were made, restricted the size of the claims to a length of 3,000 feet and a width of 50 feet; but these narrow claims, failing to cover the apices of the lodes, gave rise to interminable law-suits, which in turn led to a modification of the laws governing size of claims.

The "Pelican-Dives" properties were located under this law, and the strife between the various owners of these claims was long and bitter. While this litigation was going on shipments from the mine were occasionally made but the greater part of the ore was stolen. The "Pelican" was guarded by armed men, and in order to avoid attachments, shipments were made on Sundays. One shipment which is on record was made soon after midnight one Saturday and amounted to \$60,000. Some of the ore went to England. There was a great deal of ore taken out in the early history of the property. Between 1869 and 1872 about one and a half million dollars worth were shipped, and from 1872 to 1876 there is said to have been \$5,000,000 taken from the property, the ore running between 500 and 600 ounces per ton.

Among the attorneys employed in the litigation over these claims we find the well-known names of Belford, Teller, Orahood, Morrison, etc.

The question of apex rights was then, as now, the bone of contention, and to avoid the trouble arising from this cause the "Pelican" was consolidated with the "Dives," an adjoining claim. The death of one of the "Pelican" owners, Snyder, at the hands of Jack Bishop, a desperado, brought matters to a climax, and W. A. Hamill finally arranged a compromise, and in 1882 placed the property in New York for \$600,000. Dr. Norvin Green, President of the Western Union Telegraph Company, was one of the purchasers. The New York investors put a civil engineer named Rice in charge. Mr. Rice was a man of considerable ability as an engineer but had had no experience in mining. He proceeded to develop the mine by sinking an inclined shaft 12 ft. by 8 ft. which cost the company in the neighborhood of \$85,000. After expending \$100,000 without results, the New Yorkers became discouraged and nothing further was done by this company. Later the property was given over to lessees who mined considerable ore in the old workings.



In 1887 a Miss Tuttle, who had been a telegraph operator at Georgetown, was made local agent for the company, and she appears to have been very successful as a business manager. The mine was now known as the "Pelican-Dives," and Miss Tuttle, acting for the company, received all moneys and made all settlements with lessees.

A statement of the ore shipped from the property between January 1, 1872, and November 1, 1878, shows a total output of \$3,000,000; but this is probably less than the actual amount. The average value of the ore varied from 300 to 500 ounces silver per ton.

In 1880 Mr. Lawrence took charge of the "Pelican" and found the mine in a very dilapidated condition. Only the "two and a half" tunnel was available for work. The fine shaft sunk by Mr. Rice had fallen into decay, the timbers having rotted or been blown out by the lessees in their search for ore bodies. Mr. Lawrence has developed the mine by tunnels, from which the ore-bodies were reached by cross-cuts at intervals of about 100 feet. There are now seven of these tunnels piercing the mountain at irregular intervals, the lowest cutting it at a vertical depth of 1,800 feet. The total length of the tunnels and drifts in the mine is about thirteen miles. The vein—or ore-zone as Mr. Lawrence terms the mineralized porphyry dike—is devoid of true walls. It is about 300 feet in width and can be traced across the country for a mile and a half. There is, of course, great difficulty in defining locations fifty feet in width on such a wide ore-zone, and the absurdity of the law of the apex is apparent. Mr. Lawrence has protected the company against litigation by locating many claims on each side of the dike, the "Pelican-Dives" property now consisting of 115 claims. The result of his foresight is that he has not had a single law suit on this score since taking over the property.

There are two general classes of deposits in Clear Creek County which are commonly known in miners' parlance as "hard-" and "soft-ground" veins. To the first class, which is the best developed

belong the segregated veins in the granite. They have no walls, only general direction. The so-called "7.30" claim serves as a good illustration of these segregated veins or "stockwerks." The ore streak is from four to twenty inches in width, exceedingly rich, and, in the case of the "7.30" averages 250 ounces of silver per ton. To the second class belong the dikes, which are also the most important. The "Colorado Central" is a type of this class of deposit. This mine has had a remarkable history, having been in the courts almost since its discovery. The "Pelican-Dives" is another example of this class. The streaks of valuable minerals occurring in the dike made up an ore-zone, or mineralized territory, running through the country rock with a general direction of N. 15° E. The "Pelican-Dives" mines are opened up for a distance of 5,200 feet along one of these dikes, and in connection with the adjoining properties show a continuous line of openings for a mile and a half. The country rock is altered for 100 feet or more on either side of this dike. An interesting feature observed by Mr. Lawrence in Clear Creek County is that there is no enrichment of the veins at points of intersection. In the "Pelican-Dives" mines the best ore-bodies have been found at a depth of 300 feet, but rich ore has also been uncovered at a depth of 1,800 feet. The silver bearing minerals are polybasite, argentite, and pyrargyrite, former predominating; but there is no tetrahedrite. The average value of the ore shipped during the last year was \$75 per ton, the contents being 150 ounces silver, 0.1 ounce gold, 14 per cent. lead, 20 per cent. zinc, and the remainder silica and iron.

Between the years 1890 and 1897 the mine has yielded a net value of \$1,350,000; the total amount shipped since the property was discovered being about \$7,000,000.

All attempts at concentrating the ore of these mines have proven financial failures up to date, due to the fact that the silver bearing minerals pass off in the slimes, while the blende increases to such an extent in the concentrates as to make the smelting charges prohibitive. Experiments in amalgamation have been likewise unsuccessful.

Mr. Lawrence's paper contained many details of economic value to the engineer, apart from its historic and scientific interest. The advantages of the leasing system under which the property is being operated, were explained in detail. Blank forms and terms of contract, with costs of running levels, etc., were laid before the members for their inspection. The system of time keeping, distribution of supplies, and all the minutae incidental to this method of handling labor were patiently gone over.

## FERRIC SULPHATE IN MINE WATERS, AND ITS ACTION ON METALS.

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BY L. J. W. JONES.

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Meeting of June 5, 1897.

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About three years ago Mr. C. A. Gehrman, General Manager of the Stanley Mine at Idaho Springs, requested me to make an analysis of the water he was pumping from the shaft. He stated that its corrosive action was so great that ordinary iron pipe could not long resist it.

At that time he was pumping by steam, allowing the exhaust to pass into the water of the sump, under which conditions wrought iron pipes lasted only about a week. While the life of the iron pipe was somewhat lengthened by substituting air for steam, it was much too short to be satisfactory.

Mr Gehrman himself made a number of experiments with a view to avoiding the expense and trouble of frequent renewals of the pipe line, the maintainance of which 600 feet in length has become a serious item of expense.

Without having investigated the subject, but from general impressions, and from the remarks of mining men who had experienced the same trouble, I attributed the action to sulphuric acid in the free state, and at once suggested the use of a pipe line of pure metallic copper. This would resist the action of the sulphuric acid, and at the same time would be unaffected by the copper sulphate which existed in quite large proportion in the water, and against which no other metal would stand. Mr. Gehr-

man replied that the water had puzzled him for the very reason that copper dissolved in it readily, and not only copper, but all the alloys which he had tried. His experiments were made by boiling the metals or alloys in a finely divided condition in the water itself, using a glass flask and timing the operation so as to obtain comparative results.

This matter was submitted to me about the time that I was engaged in investigating the method of determining iron by reduction with lead, on which a paper has already been read before the Society.\* The experiments made in connection therewith suggested the cause of the extremely corrosive action of the mine water in question, and without going into details it will be sufficient to state in general terms the nature and results of the experiments.

Before going further it may be advisable to call to mind the solubility of the ordinary metals in hydrochloric and sulphuric acids, the only acids likely to occur in such waters.

Gold is quite insoluble in either sulphuric or hydrochloric acid, but dissolves readily in free chlorine.

Silver is readily soluble in nitric acid, but is insoluble in either dilute hydrochloric or sulphuric acids.

Mercury, copper and lead are affected in the same way as silver by dilute acids; lead, however, is less liable to attack by sulphuric acid, owing to its sulphate being insoluble in that acid when dilute. Tin is readily soluble in either hydrochloric or sulphuric acids, strong or dilute. Iron and zinc are readily soluble in all three acids, the iron forming with hydrochloric acid ferrous chloride, and with sulphuric acid, ferrous sulphate. Aluminum dissolves only slightly in dilute sulphuric acid when cold; more readily when boiling. Hydrochloric acid dissolves it readily, hot or cold.

It will thus be seen that gold is the only metal which completely resists the action of all the acids. Of the common metals,

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\*Feb. 3, 1896. Technical Determination of Iron.

copper and lead come next in order, while tin, iron and zinc are the most readily dissolved. Hence it would be inadvisable to use alloys containing either of the three latter metals, as they would dissolve out, leaving the more resistant metal in a spongy condition.

The first step in the investigation was a complete analysis of the water, and accordingly, a large glass bottle was filled at the sump. The sample of water on its arrival in Denver contained a considerable amount of a muddy brown precipitate, which was filtered out and analyzed with the following results:

	<i>Per cent.</i>
Ferric oxide.....	53.57
Aluminic oxide.....	2.87
Silica .....	10.85
Sulphuric anhydride .....	11.46
Water .....	21.14
	<hr/>
	99.89

The precipitated material was dried on a water bath before analysis, and is evidently a hydrated basic sulphate of iron.

The analysis of the water filtered off from the precipitate gave the following results:

	<i>Parts in one thousand.</i>
Silica.....	0.438000
Sodic chloride .....	0.134500
Sodic sulphate.....	3.117200
Potassic sulphate .....	1.554800
Aluminic sulphate .....	0.197870
Zinc sulphate.....	1.224400
Manganous sulphate.....	4.271400
Magnesian sulphate.....	4.674600
Calcic sulphate.....	6.362900
Ferric sulphate .....	60.33600
Ferrous sulphate .....	0.083370
Cupric sulphate .....	1.918010
	<hr/>
	3.0020650

The last analysis is somewhat remarkable, showing as it does the presence of an extremely small amount of chlorides, the large

number of bases in solution, and a large amount of ferric sulphate. The corrosive action of the water is undoubtedly due, in part, to the presence of copper sulphate, but its solvent power for copper was found to be entirely due to the action of the ferric sulphate.

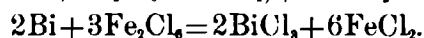
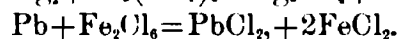
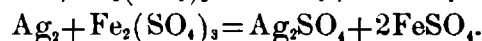
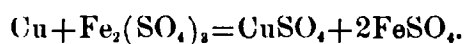
Free sulphuric acid was not present. This was proved by the presence of the basic sulphate, by the precipitation during evaporation of an additional amount of this substance due to oxidation of the remaining ferrous sulphate (if free acid were present the precipitate would not be formed), and by the amount of the acid found, which when calculated to form salts with the respective bases, showed no excess. The water had a strongly acid reaction on litmus paper, but for that matter all ferric salts have an acid reaction.

Experiments were then tried on finely divided metals with solutions of ferric sulphate, and it was found that silver, copper, antimony and bismuth readily dissolved (it must be remembered that neither of these metals is soluble in dilute sulphuric acid) while lead, as might be expected, was practically insoluble, owing to the formation of the insoluble sulphate. Gold, precipitated from a solution of the chloride by aluminum, was boiled for about ten minutes with a strong solution; but no action could be detected. The addition of salt, and boiling for some time longer showed a faint trace. When it is remembered that ferrous sulphate is a good precipitant for gold, it is seen that it cannot pass into solution by this reaction.

Experiments were then tried substituting ferric chloride for the sulphate. In this case the lead dissolved readily, since the lead chloride formed is soluble in boiling solutions. Copper, bismuth and antimony dissolved readily. Silver was converted into the chloride, but only partially. Mercury bumped violently becoming dirty grey, as if mercurous chloride were formed, which is probable. Gold did not dissolve, and after boiling for about ten minutes only a trace of ferrous iron could be detected. The

addition of  $\text{MnO}_2$ , however, producing free chlorine with the free acid, caused rapid solution.

Some of the reactions are shown by the following equations:



As will be seen by the above equations, in all cases where the metal dissolved the iron was reduced to the ferrous state, and attempts were made to use this reaction, which is perfectly definite, for the rapid determination of lead or copper volumetrically, with very fair success. The method employed was to precipitate, in the metallic form, from a suitable solution by means of aluminum foil, dissolve the precipitated metal in either ferric sulphate or chloride, and titrate the ferrous salt produced. The results are, however, liable to be too low, owing to the oxidation of the iron by the air. If the reaction were performed in a flask, in an atmosphere of steam or carbonic acid, I have no doubt that this trouble would be avoided.

The results of the practical experiments on a large scale may now be stated.

After the iron pipe was found worthless, lead-lined pipe was tried. This, while a little better than the iron, did not prove satisfactory, for the lead being too soft to withstand the friction was cut out too rapidly.

Wooden pipe was then tried, built on the Allen principle. The staves were two inches thick, of Chicago pine, banded with half-inch No. 0 iron, asphalted heavily. The inside diameter of the pipe was four inches.

This pipe lasted over a year, but proved unsatisfactory, for the wood fibres were loosened, and catching the pump packing the pipe soon became clogged with the precipitated ferric hydroxide.

A pipe of copper with a very small amount of zinc was next



tried. This soon became spongy. the zinc being dissolved out, and after a short time it gave way at the joints.

A gutta percha pipe which was tried was found to be too soft to stand both pressure and friction, giving way at the joints. The weak spots in all the pipes were where the threads for making the screw connections occurred.

Finally, as a result of the above investigations, it was decided to try bronze, with the smallest practical amount of tin, or better, aluminum. The bronze pipe has now been in place for two years, and is good for at least another year, when it will be replaced, if necessary, by one of aluminum bronze, which I think will prove entirely satisfactory. Pumping during the last two years has been done entirely by compressed air, the air compressors being worked by water power.

#### DISCUSSION.

**E. B. Kirby.**—The practical question upon which this investigation bears is that of the best material for pump parts and columns. There does not seem so much difficulty with the former as the latter, and it is one of the features in mine drainage which does not seem to have been fully developed.

A very satisfactory column pipe for corrosive waters was in use a few years ago at the Buell Mine at Central City. This was common wrought-iron pipe, with a wooden lining, which was inserted in the pipe lengths at the mine. It was made of pine staves, about three-fourths of an inch thick and one and one-half inches wide, carefully fitted by a good carpenter, and the last, or key stave, was made like a wedge, with one end smaller than the other. Its two neighbors had a corresponding taper, so that when the key was driven in from one end of the pipe the entire lining was wedged.

This seemed entirely satisfactory. The cost of lining was not great, and while the waters were remarkably corrosive the wood appeared to be sound and the iron uninjured. The old lengths I examined had been in use over a year.

**Phillip Argall.**—I cannot quite agree with Prof. Kirby's statement that the protection of pump columns from the action of corrosive mine waters is not fully solved. It has been satisfactorily solved in Europe for over fifty years, and very much in the way Prof. Kirby describes, viz.: lining the pipes with wood.

My personal recollection of this matter goes back thirty-five years, when as a boy I saw the cast-iron pipes being lined with wood for use in the Irish Copper Mines of Wicklow.\*

Later it was my privilege to be engaged in the various gradations of mining, extending from the precipitation of the copper out of the mine waters at the surface, through the manifold conditions incident to underground work, finally reaching the position of Assistant Manager. Seven years so spent gave ample opportunity to observe the utility of wood lining, and I have simply to say I never knew or even heard of its failure to protect pipes from internal corrosion.

The standard practice in the Wicklow mines consisted in lining the cast-iron pipes with half-inch soft pine strips, making the suction pipes of hard wood (usually beech) and the plungers and valves of bronze. The portion of the valve which had a bearing on the valve seat was made of leather, attached by copper rivets to the bronze valve. These rivets very often corroded. In the wood-lined pump column, accretions of ochre occurred, so that it became necessary to pass scrapers through them about once a year.

A large revenue was derived from the copper precipitated from the waters of these mines. In one case I remember the

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\*Partial analysis of the water from the Ballygahan Mine, Wicklow, by G. A. Kinahan:

	<i>Parts in one thousand.</i>
Ferrous oxide.....	'8181
Ferric oxide .....	'0490
Cupric oxide.....	'0982
Manganous oxide.....	'0230
Zinc oxide.....	'0130
Sulphuric acid.....	6'3426
	<hr/> 7'3319

mine waters were pumped out of the workings for several years after active mining had ceased, the presumption being that the copper collected as precipitate gave a profit on the work.

**Ernest Le Neve Foster.**—The action of corrosive mine waters has been a source of much trouble and expense at many of the mines in Gilpin County, and their presence has always presented serious difficulties to the miners of that section. The Saratoga Mine, in Russell Gulch, has had the reputation of having about the worst water to contend with. Pumps and column pipe were eaten out in a short time, and constant renewals not only caused great expense, but interfered very much with the mining operations. Bronze pumps and other expedients were tried, with but little improvement in conditions.

About four years ago, the property having been placed under my supervision, my attention was directed to the subject. At that time the pumping was done by a compound condensing Knowles pump, and the column was made of wrought-iron, with cast-iron flanges screwed on. It was observed that the action of the water was most severe on the wrought-iron, and that cast-iron was attacked in a less degree. Another point noticed was that the action was increased as the pressure increased, that is to say, that the lower pipes were eaten away more rapidly than those above, especially in the case where small leaks occurred, which enlarged rapidly, so that a pin-hole would, in the course of a few hours, become a large leak.

One of the chief causes of trouble was the liability to leakage around the threads of the flanges, as the slightest imperfection in these gave an opportunity for a small leak, which, as before stated, was rapidly enlarged. The bolts holding the flanges together would sometimes be eaten out, if there happened to be an imperfect gasket that permitted a leak, and in one instance called to my attention a five-eighths inch bolt was in less than forty-eight hours reduced to only one-eighth in size.

The corrosive action of this water has usually been attributed to free sulphuric acid, but no very accurate analysis of the water

has been made, the only one known to exist was made by the Keystone Chemical Company for the purpose of determining its qualities, so as to purify it for boiler use, and therefore is not as complete as is desirable. This analysis showed that a U. S. gallon contained:

	<i>Grains.</i>
Sulphate of lime.....	17·63
Sulphate of magnesia.....	3·54
Chloride of sodium.....	0·59
Sulphate of iron.....	13·79
Free sulphuric acid.....	3·20
Sand .....	6·96
Volatile and organic matter.....	5·49
Total.....	51·20

Whether the iron was present as ferric or ferrous salts was not determined. No copper is given in this analysis, but it is almost certain that at least a small amount of it would be found by a more complete analysis, although the ores of the mine do not contain many copper minerals, and those occur only in small quantity.

It having become necessary on account of the destruction of the pumps and column to install an entirely new plant, it was decided to replace the steam pumps by a Cornish pump with clack seats and clacks made of bronze, and all other parts of cast-iron. Cast-iron was also selected as the material for the stand-pipe, and the pipe and flanges were cast in one piece. This plant was installed twenty months ago, and since its installation there has never been any trouble from the corrosive action of the water, and the plungers, which are also made of cast-iron, are as smooth to-day as the day they were put in.

It might here be mentioned that the action of the mine water dripping on iron is much more severe than when the iron is simply immersed in it. A drop of the water falling from the back of a level on to a twelve-pound tee-rail will cut it in two in the course of a few weeks.

An interesting instance of immersion was presented in the

case of a steam pump which was submerged two years. The steam pipe was of ordinary wrought-iron two inches in diameter, whilst the column was five-inch cast-iron. These were side by side. On being taken out it was found that the wrought-iron pipe was scarcely thicker than paper and worthless, whilst the cast-iron one was apparently as good as the day it was put in. The same action was noticeable on the wrought- and cast-iron portions of the pump itself.

Whatever the cause of the corrosive action, whether from free sulphuric acid, as shown by the analysis, or from the presence of ferric salts, as suggested by Prof. Jones in his valuable paper, it has in this case been practically overcome by the use of cast-iron, and keeping the temperature of the mine water as low as possible. It is to the latter cause, probably more than any other, that is to be attributed the marked success made in this instance.

For the protection on the outside of the pipes painting thickly with asphaltum varnish has been found a very excellent plan in this mine.

## A LABORATORY JIG.

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BY HENRY A. VEZIN.

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Meeting of June 5, 1897.

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Mr. Vezin explained that the usual gold pan and vanning are unsatisfactory in shovel-testing ores for concentration, since they only show whether a sufficiently high extraction can be made, and are not sufficient guides as to the best method of treating the ore, nor do they give the relative amounts of coarse and fine, both of which qualities of the materials must be considered in designing works for this purpose. Trials with a small hand sieve 3 or 4 inches square, proved unsatisfactory, not only on account of the operation being exceedingly tedious, but because working by hand in a bucket or tub was not sufficiently delicate to separate particles, the falling velocities of which were not far apart. By this method quartz and pyrites could be separated, but he was unable to make even an approximately close division between galena and pyrites. With the jig this was quite easy, and any handy man who would faithfully obey instructions, could be taught to operate the jig in the course of two hours, provided he had a steady hand. The machine is geared 3 to 1, so that without moving the hand very quickly the speed of from 200 to 240 revolutions could be attained. The stroke of the plunger can be varied from 0 to  $1\frac{1}{2}$  inches. A screen of 3 by 4 inches and a plunger of the same size had been adopted so as to be able to test small quantities of ore, say, a sample of a total weight of 50 lbs. Samples of headings, middlings, and tailings were shown, which had been obtained in treating different sizes of crushed ore, varying from  $\frac{1}{4}$ -inch in

diameter down to material that would pass through 30-mesh and be retained on 40-mesh. The pulp that is finer than 40-mesh was tried by the vanning shovel. The results were very satisfactory and could be used in determining exactly how coarse the ore could be treated, how much machinery of each kind had to be provided, and how much material has to be recrushed for the purpose of obtaining the included grains of valuable material. He also showed a jig with a bed 6 by 12 inches, having six times the capacity of the smaller one, and being also arranged for hand power, though it was found best to use a 2-inch belt and power for driving it. This was designed for larger samples of ore. Mr. Vezin expressed his preference for the smaller machine, because the work could be done just as closely and just as delicately as with the larger, and because handling small quantities of ore in a laboratory is very much easier, especially if they have to be rehandled on account of first treatment not being satisfactory. The smaller jig can, of course, be driven by power if convenient.

#### DISCUSSION.

**Professor E. B. Kirby** said every one who has to do with laboratory concentration tests will appreciate the value of such an appliance as Mr. Vezin has exhibited to the Society. With regard to the comparative value of tests upon a small scale and those more nearly approaching working conditions, much depends upon the object in view.

If that object is merely to give confidence to a client by showing him the actual production of concentrates from his ore, the large jig will be of special service; but if the results are those required by the metallurgical engineer himself, small scale tests are really more convenient and accurate, and he agreed with Mr. Vezin in his preference for the smaller machine.

It is well understood that it is impossible to make any concentration tests in the laboratory which will correspond with the work of a complete mill.

Even with jigs like those before the Society, as precise results cannot be secured as those which are obtained from mill jigs where each sieve has the particular bedding and movement required for the size or class of grains fed to it.

With sands and slimes the case is even more unsatisfactory. In any test there are a number of classes and sizes from this material, each of which requires special treatment, and in the laboratory there seems to be no other way than to carefully van or pan by hand each of these classes of grains. The Professor stated that he used a pan for this work and found that on very fine slimes, too fine for sieves, it is best to first divide into classes by a rough hydraulic sorting, effected by decanting the slimes from one vessel into another.

After all is done, however, no working results are obtained, nor, in fact, is this expected. What an engineer really wishes to ascertain is, first, the percentage which will be saved, together with the ratio of concentration, and second, the data necessary to design the mill for this ore.

The chemical analysis will furnish the exact percentage of each mineral, and therefore fixes the limit for perfect work. The aforesaid laboratory tests then give actual figures of separation which are generally somewhat better than the work of a mill.

Aided by these two sets of figures the probable mill work is then fixed by judgment.

In order to design a mill, however, a mass of experimental data is necessary which is of no use to any one but the engineer himself.

The Professor was of the opinion that in every case these facts can be derived more conveniently and accurately from tests on small quantities.

Professor H. Van F. Furman said that he had listened to the paper of Mr. Vezin with a great deal of interest and hoped that it would be published in detail, together with drawings of the smaller jig. He would like to have one of these machines made for use in the laboratory of the State School of Mines. Just such



an apparatus has long been needed for laboratory tests on comparatively coarse sizes.

He could not altogether agree with Professor Kirby as he believed that with the aid of this jig, together with a spitzlutte (such as Professor Richard's), and a vanning plaque for the finer sizes, results might be obtained which would agree closely with actual mill work on a commercial scale. Tests carefully made with this apparatus should give the engineer all the data necessary to intelligently plan a mill for the treatment of any ore suited to concentration.

**Professor Jones** stated that he had used for concentration tests a trough made of sheet copper, about 7 feet long by 6 inches wide, looking very much like an ordinary house trough. The bottom of this trough was corrugated (like ordinary corrugated iron) the undulations being smooth. One end of the trough was closed, the other open.

To operate this for testing an ore, the apparatus is supported on two blocks, one being slightly lower than the other, so that it is on a slight incline. The finely crushed ore (from 40-mesh up) is fed in at the closed end (which is the higher) and a gentle stream of water allowed to flow down the trough, which is pushed backwards and forwards in a direction at right angles to its length. This enables one to make a separation into any degree of purity required, as the products are separated in a long line, which can be cut at any desired point and washed out with a wash-bottle into a pan, drained, dried and weighed. This he found far superior to a pan and much easier of manipulation, besides having the advantage of being able to obtain with it any degree of concentration desired, and any of the waste products, such as middlings and tailings.

**Mr. Vezin** declared that he could not agree with Professor Kirby in the opinion that the results obtained by the jig and the vanner in combination could only be of use in a general way, and that the probable mill work must be fixed by judgment. He said that he had made ten or more tests, some of which had to be re-

peated, as the oxidized condition of the ore rendered it difficult to decide the first time exactly where the devision should be made but the machine would give the same results as those attained on a large scale, that is to say, in a mill, except that in the final skinning there might be a slight admixture of tailings in the headings or vice versa, and the work would therefore not be absolutely as clean as that in the mill. A skilful vanner could attain exactly the same results with the vanning shovel as the best work done on a Frue vanner.

## THE EXPLOSION OF BANDAI-SAN.

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By W. L. AUSTIN.

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Meeting of June 5, 1897.

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Bandai-san is the name given to a group of peaks in Central Japan, situated on the shores of Lake Inawashiro. The highest of these peaks is 5,800 feet above sea level. On the morning of July 15th, 1888, a portion of the group was blown off by an explosion, a crater being formed on the spot where a peak had formerly stood. In this crater a small cone subsequently made its appearance.

The nature of the "eruptive" matter was interesting. It consisted for the greater part of a very fluid mud which moved with incredible rapidity down the mountain and out onto the plains. A large amount of dust was thrown into the air by the force of the explosion, which gradually settled down over the surrounding country. There was no ejection of lava, and apparently only a comparatively small number of boulders of rock was found amongst the ejectamenta. Fourteen square miles of country are said to have been covered by the débris from the mountain, damage being done as far off as ten miles from the scene of the disturbance.

The explosion occurred almost without warning and was accompanied by terrific winds.

Dr. Austin pointed out that this was a case of a crater being formed in modern times, under our very eyes, as it were—by explosive action. And also, the nature of the ejectamenta was such,

that in the course of a few centuries it will practically all be removed by the action of rains, or at least, the crater, and the gently sloping declivities from it to the plains below, will be the only remaining evidences of the catastrophe.

As another instance of a crater being formed by explosive action in historic times, the blowing off of a volcanic cone called Papandayang, in the island of Java, was mentioned. In a single night 30,000,000,000 cubic feet of materials were thrown into the atmosphere. By this explosion the mountain was reduced from 9,000 to 5,000 feet in height, with the production of a vast crater in its midst.

The great circular lakes of Bolsena and Bracciano, in Central Italy, were given as illustrations of lakes now occupying the craters of former volcanic mountains which had been destroyed by explosion. The Lago di Bracciano is six and one-half miles in diameter, and is surrounded by hills, which at their highest point rise 1,486 feet above the sea. The Lago di Bolsena is ten and one-quarter miles long by nine miles broad, and is surrounded by hills composed of volcanic matter, the highest points of which are 780 and 985 feet above the waters of the lake.

Professor J. W. Judd, F.R.S., of the Royal School of Mines, London, says in regard to these and other crater lakes: "The vast circular spaces enclosed by them, the gradual outer slope of the ring, and the inner precipices which bound the lake, all afford evidence of the explosive action to which they owe their origin."

#### DISCUSSION.

**Dr. Austin.**—In the discussion which followed, Dr. Austin pointed out the similarity of the crater lakes mentioned with Crater Lake in Oregon—so interestingly described by Professor Patton at the meeting of March 1. He stated that, as craters of large dimensions have been formed in modern times by explosive action, and as most, if not all, of the crater lakes of the globe, which have been examined, were considered to owe their origin to

explosive action, it might be possible to ascribe the formation of the Oregon lake to the same cause.

**Professor Patton** maintained that, as the sides of the present mountain showed thorough glaciation from the rim to the base, and as the moraines were not covered by débris such as would have resulted from an explosion; and, moreover, as some of the lava ejected from the former peak had actually trickled back into the crater, apparently after the upper portion of the mountain had disappeared, the presumption was, that the peak had fallen into what is the present crater, which is the conclusion arrived at by the U. S. Geological Survey who have carefully investigated the Crater Lake region.

**Dr. Austin** replied that, as he had not visited the crater lake in question, he could not express any decided opinion as to its formation, but it was difficult to understand how a cavity "several square miles in extent" could have been excavated directly under a volcanic mountain of the class to which the former peak must have belonged; and that, if lavas of the consistency of basalt (45 to 55%  $\text{SiO}_2$ ), andesite (50 to 65%  $\text{SiO}_2$ ), and rhyolite (65 to 80%  $\text{SiO}_2$ ), rising—as they probably did—from considerable depths within the earth, still retained sufficient solvent power to dissolve out of the cold, siliceous crust a cavity of such enormous dimensions—and so convenient for the mountain to drop into—the proofs of such an occurrence would be of the greatest interest in connection with the science of volcanology.

It is quite conceivable, however, that a lofty cone—composed of lapilli and scoriaceous materials, with more or less lava—could be blown off by an explosion, or series of explosions, such as occur at the present day, and that the force of an explosion of this kind might throw the material of which the peak was composed to a considerable distance. Nor would it be necessary that *all* the moraines at the base of the mountain should be covered by the débris. If the explosion occurred during an eruption of lava,

a portion of the latter—interrupted in its flow—might even have trickled back into the new crater.

Conclusive evidence of the falling of a lofty volcanic peak into a hole several square miles in extent excavated under its base, will be awaited with interest.

## QUESTIONS FOR DISCUSSION.

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By L. J. W. JONES.

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Meeting of September 11, 1897.

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Professor L. J. W. Jones proposed the following questions for discussion in an informal way:

In blast furnace smelting for lead, why does that metal pass into the matte; why is not the matte purely an iron sulphide, or, when copper is present, an iron-copper sulphide?

Since lead is always found in mattes formed in this process, what conditions govern the percentage of this metal in these mattes, it being well-known that some mattes are quite low in lead, while others carry a high percentage?

### DISCUSSION.

Mr. Argall mentioned the case of the La Plata dump in Leadville as having yielded matte running high in lead, but did not offer any explanation for this occurrence.

Dr. Austin stated that the subject had received considerable attention from European metallurgists, especially in the early part of the present century, with the result that mattes were generally considered to be combinations of sulpho-salts.

The disposition of one or the other metal to enter a matte might, therefore, be due to the presence of other sulpho-salt building elements. Antimony, for instance, has a tendency to form sulpho-salts with lead, silver and gold. Arsenic, with nickel, cobalt and iron. If pyrite is present in considerable amounts in the charge (10 to 11 per cent.), double compounds are very apt

to be formed with lead sulphide. The difficulty of separating sulphide of lead from sulphide of iron, or what is equivalent, the weakening of the precipitating effect of iron on sulphide of lead when sulphide of iron is present, has long been known. Fournet's law with regard to the relative affinities of the metals for sulphur, is subject to modifications when arsenic or antimony are present.

It is probable, also, that furnace conditions largely influence the metals in entering the matte. The composition of the slag, the proportion of fuel, and even the dimensions and shape of the furnace, are factors in the problem.

As this may prove an instructive subject for discussion, he proposed that the matter should be brought up at some future meeting, and, in the meantime, any members wishing to contribute their experience to the discussion, are requested to address the Secretary, and, if possible, to prepare papers on the subject.

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**Mr. Henry A. Vezin**, in speaking of ore-dressing, called the attention of the Society to the use of the jig for the purpose of avoiding very fine screening.

The first instance of the kind which he has observed in the West was at the Conqueror Mine, North Empire, in this State. At these works a jig is employed as an intermediary machine in the transition from sizing by screen to water-sizing. The finest screen used is eight-mesh. That passing through the screen goes to a jig which takes out all the pyrites down to  $\frac{1}{16}$ " in diameter, the coarsest pieces being about  $\frac{1}{8}$ ". This is contrary to the usual practice, where the material passing through the screen is subjected to further sizing. The tailings from the jig are elevated to the two Huntington mills, and crushed finer, before being passed to the pointed boxes over the Frue vanners. By this arrangement the coarser particles of pyrites, passing through the eight-mesh screen, are prevented from being crushed in the Huntington mills, without the intervention of any fine screen. He spoke of



some cases in the West where, for the purpose of attaining the same end, screens as fine as sixty-mesh—that is to say, with holes  $\frac{1}{16}$ " in diameter—have been used. This is objectionable, both on account of the low capacity of the screen and the cost in wear and tear. Of course, the arrangement at the Conqueror Mill allows particles less than  $\frac{1}{16}$ " to pass into the Huntingtons, but, owing to the agitation of the water in these, it is probable that they are discharged without being crushed much finer.

The best arrangement would consist in having a small V box immediately in front of the jig, say, not over 6" in depth. This would take out all the coarse gangue containing included grains, together with all the coarse pyrites which would go to the jig, and the overflow of the V box would carry off gangue of, say,  $\frac{1}{16}$ " together with pyrites of  $\frac{1}{16}$ " diameter, to be distributed over the vanners. The discharge from the tail-end of the jig would then contain nothing but gangue requiring finer crushing for the purpose of liberating included grains.

A jig inserted in this same way can serve another very useful purpose, by enabling the ore dresser to take out all the coarser gangue which requires still finer crushing, without the use of a fine screen. Let us assume that the ore is crushed by stamps to pass a 10-mesh screen, or that the material is  $\frac{1}{16}$ " in diameter, and that, for the purpose of liberating included grains in the coarser particles, it is necessary to crush them to 40-mesh, or, say,  $\frac{1}{16}$ " in diameter. It can be done as just suggested, by a short V box placed immediately in front of the jig, with a straight downward discharge and a proper pressure of fresh water, to prevent the fine slimes from going out with the coarse particles. The straight discharge is essential, as the elbows in ordinary V boxes are apt to clog. The very fine sands and slimes—40-mesh and less—pass on to the other water sizers, and the discharge of the jig goes to the crushing machines—rolls or Chilean mill—to be crushed to 40-mesh. In this way water sizing can be used for taking out the gangue that needs finer crushing, without subjecting the pyrites

already free to any further comminution, which latter would be the case if a fine screen is used and *no* jig.

**Mr. R. C. Hills** suggested that the re-crushing of tailings often involved more expense than was justified by the additional saving.

**Mr. Vezin** replied that, in this particular case, the additional saving was probably from \$1.20 to \$1.40 per ton—the value of the original ore being \$12.67—and the total saving 96 per cent. He added that, with ore from the southwestern part of the State, jigging was commenced with particles  $\frac{1}{4}$ " in diameter, and carried down to  $\frac{1}{16}$ ". There were saved in the jigs,  $21\frac{1}{2}$  per cent.; from the fines below  $\frac{1}{16}$ " in diameter,  $23\frac{1}{2}$  per cent.; and from re-crushing the tailings of the jigs down to  $\frac{1}{16}$ ",  $22\frac{1}{2}$  per cent.

**Mr. Vezin** further stated that his attention had been first called to the method described, by Mr. Schell in 1878. This gentleman was foreman of the great works at Clausthal in the Hartz Mountains, and is also the inventor of the syphon discharge for jigs. At these works, all the material, from the finest screen, which had holes of about  $\frac{1}{16}$ " in diameter, was passed over a jig, for the purpose of taking out all the galena of from  $\frac{1}{16}$ " down to  $\frac{1}{32}$ " in diameter, before allowing the material to pass to the water sizers, his object being to prevent the coarser galena from clogging up the elbows in the pipes of the V boxes. The product from this jig in headings was very great.

# NOTES ON A PECULIAR OCCURRENCE OF TELLUR- IUM IN A GOLD ORE FROM THE GREAT BOULDER REEF, WESTERN AUSTRALIA.

BY RICHARD PEARCE.

Meeting of October 2, 1897.

The ore looks like a highly metamorphosed rock impregnated with pyrite; the presence of a dark greenish talcose-looking material is well marked, but there is nothing in the general appearance in the rock to indicate the presence of gold, tellurium or vanadium. An examination of the concentrates, however, which were produced by vanning, shows the presence of all three elements in well marked quantities.

One great drawback in the investigation of a mineral of such a character is the difficulty of procuring sufficient material for analysis. I have been able to get, however, some two or three grammes of what appears to be a mineral of a somewhat mixed character, which has been analyzed by Mr. F. C. Knight with the following results:

SiO <sub>2</sub>	30.31
Fe <sub>2</sub> O <sub>3</sub>	11.70
Al <sub>2</sub> O <sub>3</sub>	9.79
V <sub>2</sub> O <sub>5</sub>	16.64
CaO	6.39
MgO	1.05
Te	0.42
Au	0.52
S	4.11

H<sub>2</sub>O, K<sub>2</sub>O, CO<sub>2</sub>, etc., not determined.

The finely powdered mineral was treated for some time with nitro-hydrochloric acid, and the soluble portion was examined separately from the insoluble portion with the following results:

<i>Soluble.</i>	<i>Insoluble.</i>
Fe <sub>2</sub> O <sub>3</sub> ..... 32.72	SiO <sub>2</sub> ..... 45.25
Al <sub>2</sub> O <sub>3</sub> ..... 8.74	Fe <sub>2</sub> O <sub>3</sub> ..... 1.37
CaO ..... 16.34	Al <sub>2</sub> O <sub>3</sub> ..... 10.32
V <sub>2</sub> O <sub>5</sub> ..... 7.43	CaO ..... 1.49
Au ..... 1.57	MgO ..... 1.57
Te ..... 1.27	V <sub>2</sub> O <sub>5</sub> ..... 24.32
S ..... 12.48	

It will be seen from the presence of a quantity of S which, in all probability, is combined with iron as pyrite, that the material is impure, and can be only regarded as a mixture perhaps of some well defined vanadium mineral with pyrite, one or more of the tellurides of gold and silver and dolomite.

If we disregard the soluble portion entirely except so far as the V<sub>2</sub>O<sub>5</sub>, we find that the insoluble portion consists of:

	<i>Knight.</i>	<i>Genth.</i>	<i>Roscoe.</i>
SiO <sub>2</sub> .....	43·65	47·69	41·25
Fe <sub>2</sub> O <sub>3</sub> .....	1·32 (FeO)	1·67	1·04
Mn <sub>2</sub> O <sub>3</sub> .....			1·45
Al <sub>2</sub> O <sub>3</sub> .....	9·95	14·10	14·34
CaO .....	1·43		0·61
MgO.....	1·51	2·00	1·96
V <sub>2</sub> O <sub>5</sub> .....	27·11	20·56	28·85
K <sub>2</sub> O .....		7·59	8·25
Na <sub>2</sub> O .....		0·19	0·72
H <sub>2</sub> O.....		4·96	2·12

This analysis shows a remarkable analogy in composition to the mineral known as roscoelite which may be said to consist of a silicate of vanadium and alumina and potash; and we have it on the authority of Dana that this mineral roscoelite is only slightly soluble in acids. "Roscoelite," according to the analysis of Roscoe and Genth on material from different localities, is given as follows (see above).

The only known localities given for roscoelite are California (Granite Creek, near Coloma, El Dorado Co.,) and Magnolia

District, Colorado, although the mineral analyzed by Genth from Colorado is thought by him to be closely allied to roscoelite – perhaps a variety.

In both these localities it is associated with gold, as in the Australian ore.

In some experiments which were made to determine the methods best adapted to the economic treatment of the ore from the Great Boulder Reef, I was struck with the large percentage of dolomite which was found to be present in the material. Dilute hydrochloric acid was found to dissolve in one case as much as 41.62 per cent. of the mixed carbonates of lime and magnesia, and this sample of the ore contained 20.2 per oz. gold per ton. Another sample showed that 31.2 per cent. of the ore was soluble in dilute acid, the ore assaying 17 oz. Au and 8 oz. Ag per ton.

Fifty grammes of the sample gave, by vanning, three grammes of concentrates, consisting mainly of pyrite. Under the microscope these concentrates showed a greyish mineral, which I have no doubt is one or more of the telluride minerals. Intimately associated with the tellurides are a number of rounded grains having a brown color, and showing here and there bright surfaces of metallic gold. The brown material I imagine to be an altered telluride, the color being due to an oxidized form of tellurium, mixed with brown metallic gold as seen in the oxidized ores of Cripple Creek.

On treating the richest portion of the concentrates with nitric acid the pyrite completely dissolved together with the tellurium compound, and the gold was left in bronze colored, spherical, hollow particles, with only a few specks showing a bright gold luster.

In my early investigations of this ore I was led, from the very basic character of the mineral, to suppose that the vanadium existed in the form of the mineral vanadinite, a vanadate of lime, which is described as a doubtful substance, regarded by Rammelsberg as probably a mixture of augite and vanadate. Some recent

examinations, however, would, I think, almost indicate the existence of the mineral roscoelite.

Per cent.  $V_2O_5$  in mass of rock = 0.78%.

#### DISCUSSION.

**Dr. N. O. Holst**, Government Geologist from Stockholm, who was introduced as a guest of the Society, confirmed Mr. Pearce's opinion that the rock of which he got specimens from Great Boulder Main Reef, was a schist impregnated with gold telluride, auriferous iron pyrites and free gold, and that it was interbedded in the common schists of the country, which, in the Kalgoorlie District, generally stand vertical. Of these auriferous beds there are several parallel lodes. The principal ones, from west to east, are: the three rather short Ivanhoe Lodes, the Great Boulder-Great Boulder Main Reef Lode, the Lakeview Consols-Perseverance Lode, the Australia-"Kalgoorlie" Lode, and Hannan's Brown-Hill Lode. The geological occurrence of the West-Australian telluride ore was, therefore, entirely different from the same ores in the Cripple Creek District, where, as is well known, the formation is eruptive and volcanic. This difference makes the "Kalgoorlie" deposit ("Hannan's formation") more regular and reliable than the Cripple Creek deposits which often make a sharp turn, and go over from one system of fissures to another. Dr. Holst had observed the mica and graphite-like mineral without determining its nature, and which Mr. Pearce had found to be a vanadium mineral. It is not rare in the Great Boulder Main Reef.

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**Mr. Henry A. Vezin** called attention to the fact that, in his discussion of Mr. G. M. Gouyard's paper on the "Magnetic Separation Applied to Sulphide Ores," which was read at the meeting of February 1st of this year, the rule which he laid down—that the cost of crushing was inversely proportional to the average diameter of the pieces crushed—was applied to brittle ores, such as sulphides and silicious ores, but not to those containing clay or kaolin in

large proportion, provided the crushing is done dry. The clayey material packs in the rolls, and obstructs the screens, so that the capacity of the machinery is very much reduced, even with perfectly dry ores. Of course, in crushing wet, say, for concentration, the rule applies even with clayey ores, since the water removes the clayey material.

After the adjournment of the meeting, Mr. Vezin showed to those interested in the 3"x4" laboratory hand jig which he had described in the meeting of June 5th, 1897, the same machine, with a power attachment, by means of which the jig could be driven from any line shaft at any required speed. By giving a thumbscrew one turn, it can be thrown in or out of action, or changed from power jig to hand jig.

SOME PRODUCTS FOUND IN THE HEARTH OF AN  
OLD FURNACE UPON THE DISMANTLING OF  
THE TRETHELLEN TIN WORKS,  
TRURO, CORNWALL.

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BY WILLIAM P. HEADDEN, PH.D.

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Meeting of November 8, 1897.

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The suite of samples forming the subject of the following notes, was presented to me some five years ago by Dr. Richard Pearce. I was at that time keenly interested in the tin compounds; but change of position and press of other duties have prevented me, up to this time, from presenting the results of their examination.

Dr. Pearce gives me the following information relative to the samples. They were found in the hearth of an old furnace in the Trethellen Tin Works, at Truro, Cornwall. The works were dismantled about 1892, though they had been idle or abandoned for about twenty-three years previous to that date. The furnaces were very old, having been in use for at least sixty, and perhaps for nearly a hundred years. The ores smelted in these works were the usual Cornish tin ores, carrying, among other things, arsenopyrite, which was probably the source of both the arsenic and the cobalt found in these compounds.

Dr. Pearce demonstrated the presence of cobalt in this arsenopyrite and published an article upon the subject in 1871.

There is no premeditated order in the following notes. One of the smaller and apparently purer samples was taken first. This



was a mass of small, dark-gray crystals which, under the microscope proved to be of two distinct forms; one of them belonging to the monoclinic system, showing the pyramidal and prismatic faces, but flattened into thin plates by the development of the clinopinacoid; the second form appears to belong to the orthorhombic system.

The plates are invested with small crystals of metallic tin, and the mass of crystals has the same material (tin), as its cement, which is so abundant that the mass is rather malleable under the pestle, though the crystals themselves are very brittle.

The whole mass went into solution with separation of ferric oxid upon successive treatment with nitric acid and sodic hydrate. After decantation of the alkaline solution, washing and treatment of the residue with nitric acid, there remained a small quantity of sand, mixed with a few spangles of an alloy which had resisted the acid. The luster of these spangles is highly graphitic, and their form, in so far as it could be recognized, was suggestive of this substance. The quantity of these was too small for even a preliminary examination.

The deportment of these compounds toward nitric acid is wholly different from that of the alloys described by me in 1892, as is also their form.

Hydrochloric acid attacked the mass violently with the evolution of hydric sulfid. The use of these acids was, therefore, excluded in the separation of the metallic tin from the crystallized compounds. I had recourse to ferric chlorid, which, as is known, dissolves metallic tin quite readily. I succeeded in removing the excessive tin by the use of this solvent, and obtained a mass of dull gray crystals. These consisted of two forms, as already noticed, and the plates had the clinopinacoid, sunken, but the face itself, where intact, was smooth and had a strong metallic luster; they also had a full black color, while the other crystals have a dark gray color. These latter could now be seen to be orthorhombic. The forms recognizable were, 110, 100 and 101. Some of the crystals show the surfaces 110 and 101 only, and a few of them

have the three pinacoids 100, 010 and 001. These forms were the most unsatisfactory to make out, still, I think that there is no doubt but that these are orthorhombic crystals with the above surfaces developed.

The product obtained by treatment of the mass with ferric chlorid seemed to be quite free from excessive tin, and was very brittle, but was a mixture of two compounds. One of them was soluble in hydric chlorid with evolution of hydric sulfid, and the other was not attacked. It seemed unavoidable that one compound should be sacrificed to obtain the other pure, as they are both wholly non-magnetic and are both attacked by nitric acid. To obtain some basis for the identification of the compound soluble in hydric chlorid, a portion of the mixed material was analyzed, with the following result:

As .....	42.347
S.....	3.723
Sn .....	16.947
Fe .....	30.518
Co .....	3.006
Cu .....	Trace
Ni.....	Trace
Insol. ....	2.557
	<hr/>
	99.098

The portion soluble in hydric chlorid contains but little silicic and no tungstic acid, and is also free from arsenic, antimony, and cobalt. The residue was entirely free from the monoclinic crystals and was mixed with but a small amount of sand. The residue, insoluble in hydric chlorid, has the following composition:

Sand .....	1.760
Sulfur.....	0.536
Cobalt.....	3.640
Tin.....	2.847
Iron.....	38.304
Arsenic.....	53.224
Nickel.....	Trace
Copper.....	Trace
	<hr/>
	100.311

The specific gravity of this compound as determined is 7.6509, which becomes 7.9414 when corrected for 1.76 per cent. silica, sp.gr. 2.6. Calculating the arsenic, iron and cobalt, which amount to 95.168 per cent. of the total, to 100, we have:

	<i>Per Cent.</i>	<i>At. Eq.</i>		<i>At. Ratio.</i>
Arsenic.....	55.927	77.70	77.70	1.000
Iron.....	40.248	71.85	78.35	1.008
Cobalt.....	3.825	6.50		
	100.000			

We may not, as a matter of fact, in the light of our knowledge of the combinations of iron and tin, be justified in rejecting the sulfur and tin, amounting to something over three per cent. They have, however, no influence upon the atomic ratio, if we consider them as replacing part of the arsenic in the compound. I feel quite justified in doing this because, if the sulfur were present as  $\text{SnS}$ , it would be liberated as  $\text{H}_2\text{S}$ ; and, if the tin were present as  $\text{FeSn}$ , it would have gone into solution with the  $\text{HCl}$ , and furthermore, it would remain upon solution of the mass in nitric acid. I am, therefore, inclined to the opinion that the real formula of the compound is to be written  $(\text{FeCo})(\text{AsSnS})$ ; and the simplest expression of this is  $\text{FeAs}$ , in which a part of the iron has been replaced by cobalt, and a part of the arsenic by sulfur and tin. There is, however, another question suggested by the next compound to be considered, to-wit, whether this may not be a molecular combination of  $\text{SnS}$  and  $\text{FeAs}$ . Owing to the crystal line form and deportment of the compound toward solvents, hydric chlorid in particular, I hold this to be very improbable, and believe the formula as given to be correct. This point would scarcely be raised were it not for some interesting facts to be given subsequently.

The portion soluble in hydric chlorid amounted to 16.44 per cent. of the crude product, as obtained by treating the mass of crystals with ferric chlorid. The residue insoluble in ferric chlorid and washed as free from sand as was practicable, was just

a trifle less than 40 per cent. of the original mass, or, about 60 per cent. of the original was sand and tin. The residue retained the form of the original perfectly, so long as it was untouched; but the gentlest pressure caused it to fall to pieces, and further examination of it as a mass was impossible. I do not know whether the ferric chlorid dissolved any other constituents than the tin or not. Only a very gentle heat and a somewhat dilute iron solution was used. I am quite convinced that continued digestion with a concentrated, hot ferric chlorid solution attacks the stannous sulfid.

In order to determine the composition of the portion soluble in hydric chlorid, a larger portion was treated with this reagent and the solution analyzed. The sulfur was calculated from the difference between the amount found in the analysis of the insoluble portion and the total found in the mixed material. The precaution was taken to digest the insoluble portion in potassic hydrate to remove any sulfur which might have been separated during the treatment with hydric chlorid. The results obtained were:

	<i>Per Cent.</i>	<i>At. Eq.</i>	<i>At. Ratio.</i>
Silica.....	1.78		
Iron.....	4.75	8.5	68.3
Copper .....	0.44	0.7	
Bismuth.....	Trace		
Tin.....	69.62	59.1	
Sulfur.....	22.51	70.4	70.4
Lime .....	Trace		1.00
Magnesia .....	Trace		1.03
	<hr/> 99.10		

or  $\text{Fe} + \text{Sn} : \text{S} :: 1 : 1$ ; or  $(\text{FeSn})\text{S}$  with  $\text{Fe} : \text{Sn} :: 2 : 13$ , nearly, which is simply stannous sulfid with two-fifteenths of the tin replaced by iron.

Having a second specimen which resembled the one just described in all respects, except that it was surmounted by a much thicker coating of monoclinic plates, not distinguishable from those already mentioned, I picked out a small quantity of them for

analysis. I supposed that I had about  $\cdot 5$  of a gram, but really had less than  $\cdot 2$ ; still, as the material was perfectly clean and the plates were all large, so that the probability of there being a mistake as to their identity was very small, I resolved to attempt the analysis with the following results:

	<i>Per Cent.</i>	<i>At. Eq.</i>		<i>At. Ratio.</i>
Iron.....	17.949	32.0	} 35.5	1.06
Cobalt.....	2.037	3.5		
Sulfur.....	10.671	33.3	33.3	1.00
Arsenic.....	27.166	36.2	36.2	1.08
Tin.....	43.108	36.5	36.5	1.09
	100.929			

The compound has the formula  $\text{FeSnAsS}$ , or probably  $\text{FeAs}$  plus  $\text{SnS}$ , with a portion of the iron replaced by cobalt. It will be noticed, upon calculating the ratio of the cobalt to the iron, that it is considerably higher than in the analysis of the iron arsenid.

The next specimen examined was a mass of shining black monoclinic crystals, surmounting a piece of slag. There was a thin layer, forming the base of this mass, which contained arsenic, iron and cobalt. I did not examine it further, but consider it identical with the iron arsenid already given. The quantity obtained pure was small, but the crystals were comparatively large and showed the same forms as those already given, except that a brachydome was observable upon a few crystals; this surface was very subordinate.

The mass of crystal plates, together with the material forming the base, was treated with ferric chlorid to free them from as much tin as possible. It soon became evident that the ferric chlorid solution attacked these more readily than it had attacked the other samples, and I was afraid to push the treatment too far. The analysis of the material selected after this treatment, gave as the composition of the crystals:

	<i>Per Cent.</i>	<i>At. Eq.</i>		<i>At. Ratio.</i>
Sulfur.....	17.134	53.5	53.5	1.00
Iron.....	2.905	5.2	} 73.3	1.37
Tin.....	80.413	68.1		
	100.452			

This ratio shows a considerable excess of tin. Any assertion as to the form in which this tin is present, would be based upon surmise only. I have no observed facts to offer.

The sulfur was determined by collecting the hydric sulphid evolved by treating the crystals with strong hydric chlorid, in an alkaline solution of potassic arsenite, subsequently oxidizing with chlorin gas, and precipitating the sulfuric acid formed as baric sulfate.

It is stated in Gmelin-Kraut's *Handbuch der Anorganische Chemie* that the stannous sulfid dissolves tin in all proportions; this may explain the excessive tin present, but an examination of the material renders this explanation hard to accept. Another explanation might be that the tin and iron are in combination with each other, forming one of the stannids of iron, but this explanation is no more satisfactory than the one already suggested, for the highest ratio for the iron to the tin is 1:2 in which case we would have 5 FeSn, to deduct, leaving the atomic equivalents of the sulfur to the remaining tin as 53.5:58 or as 1:1.085 which would be a satisfactory ratio if it were evidently the natural one, to be derived from the analysis. In either case it seems evident that the principal compound, and the one determining the form of the crystals, is SnS.

The next sample was a small mass of tin-white plates, with an exceedingly high luster, and having a slightly bronzy tarnish. The form of the plates is by no means distinct, but I believe them to be rhombohedral. I could not remove the excessive tin, as the crystals are attacked by hydric chlorid with the evolution of hydric arsenid, and the separation of a brown solid. Ferric chlorid also dissolves them with the separation of black flakes, and the fragments of the crystals remaining have a brownish-black color.

They are easily cut with a knife and are somewhat flexible. They are completely soluble in aqua regia, and analysis showed their composition to be:

	<i>Per Cent.</i>	<i>At. Eq.</i>	<i>At. Ratio.</i>
Tin.....	90.414	76.62	6.02
Arsenic .....	9.441	12.72	1.00
	<u>99.855</u>		

This appears to be a new alloy of tin and arsenic having the formula  $\text{Sn}_6\text{As}$ .

The only statements that I can find relative to the combinations of arsenic and tin are to the effect that they alloy when heated together, forming a white, resonant, and if too much tin has not been added, a brittle mass, which has a laminar structure and is less fusible than tin. The alloy is readily attacked by hydric chlorid, if it does not contain too much arsenic, with the evolution of hydric arsenid, leaving a brown residue richer in arsenic. When the alloys are too rich in arsenic to be attacked by hydric chlorid, they give up a part of their arsenic when heated and yield a residue soluble in hydric chlorid.

The alloy here described crystallizes in six-sided plates and differs in both luster and hardness from metallic tin, which appears on the crystals in the form of minute globules. While it was impossible to avoid some tin in the material analyzed, I do not think that there was enough free tin in the sample, as picked for analysis, to vitiate the results.

The last sample of these products is scarcely less interesting than the others, because it presents the formation of an artificial wood tin. It consists of a nucleal residue of metallic tin with a layer of stannic oxid on either side of it varying in thickness up to an inch; this stannic oxid is banded and in some places shows the concentric structure of the typical wood tin. In hardness it is in places only a little inferior to ordinary wood tin; the streak is quite light, as is also the powdered substance; some of the darker bands are slightly iridescent.

The oxygen was determined by reduction in an atmosphere of hydrogen. The composition was found to be:

	<i>Per Cent.</i>	<i>At. Eq.</i>	<i>At. Ratio.</i>	
Tin.....	78.969	65.2	65.9	1.00
Copper .....	0.240	0.38		
Iron .....	0.091	0.20		
Cobalt.....	0.060	0.1		
Oxygen.....	22.550	140.9	140.9	2.13
Arsenic.....	Trace			
	99.910			

It would seem that the wood tin is the product of the oxidation of the mass of tin at low temperatures, possibly with the aid of some other agent of which we have no suggestion. It would have been interesting in this connection to have determined the composition of the residual tin, but my time has not, up to the present, permitted of this. One would judge the tin to be more impure than the analysis of the stannic oxid formed from it would indicate.

As we are not aided by an intimate acquaintance with the conditions under which these compounds were found, we are left to judge of the manner of their formation by such signs as we may detect, guided somewhat by what we know of their properties. The arsenid may have been formed in a mass of tin, and the more easily fusing metallic tin may have drained off after the plates of the arsenid had formed; there were some indications that such may have taken place, but it was not so clearly indicated as to preclude the possibility of the building of the masses in some other way. The crystals, however, are remarkably clean to have been produced by this method.

I cannot surmise whence the vapors may have come from which the crystals of stannous sulfid, particularly those upon the slag, were formed; but the cleanness of the slag and other conditions of the sample, all indicate that the compound has, in this case at least, been formed by sublimation.

There seems, however, to have been two periods in the forma-



tion of the mass of crystals, for the first deposit is not a sulfid of tin but an arsenid of iron. That there was tin in the atmosphere in which these crystals were formed, is abundantly indicated by the deposition of small globules of tin on the surface of stannous sulfid crystals and its presence in the crystals in excess of that required to form  $\text{SnS}$ . The property of  $\text{SnS}$  to dissolve metallic tin has been observed by many writers, and its occurrence in the crystals does not suggest its presence as liquid tin at the time of the formation of the crystals, or subsequently thereto. That the tin, arsenic, and sulfur should have been brought to the place of final deposition in the form of volatile compounds is easily conceivable, but in what form the iron may have been furnished for the formation of the arsenid is not so easily explicable; still, as the order of deposition is not sharply confined to that of the arsenid of iron first, but the two compounds having been deposited in part, at least, simultaneously, we conclude that, while the major portion of the arsenid was deposited before the sulfid was formed, it was probably due to the fact that the heat was still too high for the deposition of the sulfid, but that the two compounds were still being formed. The relatively large size of the arsenid crystals indicate, in this instance, an atmosphere poor in the compounds forming the arsenid. The other samples would not have justified any inference as to the manner of formation, but with the aid of this sample the formation of the others, consisting almost exclusively of the arsenid, but containing in the upper portion of the mass crystals, in one instance of stannous sulfid, and in the other a molecular combination of the sulfid and arsenid, becomes explicable.

In regard to the time required for the formation of these interesting bodies we have nothing to guide us to a judgment. In the case of the stannic oxid or wood tin, I have no doubt but that the process is going on at the present time, very slowly, it is true, but an examination of the sample will convince any one of its probability. In the case of the arsenid of tin, I am inclined to explain its formation in the same manner that has been suggested

for the sulfid of tin, but admit the possibility that these crystals may have been formed in a bath of tin, which, being more fusible than the crystals, may have been absorbed by brick or something else, at least had opportunity to drain away; still, as these, too, were found in the old hearth, it is not easy to understand by what accident the liquification should take place.

The arsenid of iron has still another interest in, that it has the form of loellingite and bears to this mineral the same relation that troilite, assuming the composition of this mineral to be represented by the formula  $\text{FeS}$ , does to pyrrhotite.

There is, fortunately, no question of the atomic ratios in the analysis of our material; it is the simplest possible, 1:1, and gives for the formula  $\text{FeAs}$ , with a portion of the iron replaced by cobalt, as is also the case in some of the loellingites.

The series of samples is, it is true, wholly artificial, but the time required to produce these compounds, or perhaps better, the period during which they may have been forming, was so long, that they are comparable to real minerals, with perhaps the exception of the stannic arsenid.

I would again acknowledge my indebtedness to Mr. Pearce for the suite of specimens and all of the information which I have obtained concerning them.

#### DISCUSSION.

**Dr. Richard Pearce.**—It may not be out of place for me to add some few details in reference to Dr. Heddén's instructive paper. The specimens which have been described, were obtained from the foundation of an old tin smelting furnace which had been in use during a very long period. The presence of cobalt replacing a portion of the iron in one of the specimens referred to, may be explained by the fact that cobalt is known to be intimately associated with tin ore in most of the Cornish mines.

My attention was first called to this fact in 1871, when I discovered that the tin oxide which had been separated from its gangue by the ordinary method of concentration, as practised in

Cornwall, contained appreciable quantities of cobalt. In a paper read at a meeting of the Royal Institution of Cornwall entitled "Notes on the Occurrence of Cobalt in Connection with the Tin Ores of Cornwall," I attributed the presence of cobalt to the association of arseno-pyrite with the tin ore, this mineral being often found to contain appreciable quantities of cobalt.

In the concentration of tin ores an intermediate process of calcining the concentrates is found necessary, so as to get rid of sulphur and arsenic, and to change the iron present into an oxide having a lower specific gravity than the tin oxide, so that a separation can be effected by a series of subsequent workings. In this calcining process the whole of the arsenic is not eliminated, a portion of it being probably converted into a fixed compound, arseniate of cobalt, which, in the final reduction of the tin ore in the smelting furnace with anthracite coal, is reduced to an arsenide, and enters into the composition of what is known as "hard head," a product in tin smelting which may be said to be a speiss. An analysis of a sample of this product in 1871 gave 44 per cent. cobalt, 53.8 per cent. iron, and 18 per cent. arsenic.

By a curious coincidence the volume of the Transactions of the Royal Institution of Cornwall, which contained my paper on the occurrence of cobalt with the tin ores of Cornwall, also contained, immediately following it, a paper entitled "Notes on a Portion of the Incrusted Surface of a Block of Jew's Tin," by J. H. Collins. After giving a description, accompanied by an analysis, of the incrustation, Mr. Collins says:

"The crust, therefore, appears to be composed chiefly of peroxide of tin, somewhat resembling the native variety of cassiterite, called wood tin, but neither so hard nor so heavy. It has, no doubt, been formed by the slow oxidation of the outer surface of the block of metallic tin. The slowness of the change is, perhaps, indicated by the dense condition of the incrustation."

The artificial wood tin to which Dr. Headden refers in his paper, occurred in considerable quantity, the rapidity of its formation being perhaps due to the heat from the furnace. The "Jew's tin," or "Jew's house tin," as it is generally called in Cornwall, is a

product of very primitive smelting, probably dating back some hundreds of years, and is found in the neighborhood of old "blowing houses," as the smelting houses are called. The art of tin smelting in early times was, I believe, conducted by Germans who found their way into Cornwall under the patronage of King John in the thirteenth century.

Dr. Headden's theory of the formation of the interesting tin compounds with arsenic and sulphur, which he has described, viz.: by sublimation, may be correct. My own experience, however, would lead me to believe that the crystals were produced from a bath of tin containing the elements of these compounds in solutions, which crystallized out from a solution or mother liquor during a process of slow cooling.

I have found the most beautiful crystals of an alloy of gold, silver and lead, in perfectly regular octahedrons which have been produced in this way, that is to say, crystallized out from a lead solution, the lead having drained off to a lower depth in the hearth of the furnace, and having become converted into red lead and litharge. I could mention other compounds which, undoubtedly, had a similar origin.

## SOME TELLURIUM VEINS IN LA PLATA MOUNTAINS.

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By W. L. AUSTIN.

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Meeting of December 4, 1887.

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The veins cut through the heart of these mountains in a general northeast and southwest direction. They may be traced from one gulch to another for a distance of a mile or more, passing through gaps in the intervening ridges. On the west bank of La Plata River, about six miles from the old town of Parrott, a number of these veins may be observed occurring more or less parallel. They vary in width and dip, and have the same general strike; but in some instances they are known to intersect.

Further up the stream and to the eastward of it, at the Columbus Mine, the vein there being exploited is much larger and of a different character from the group first mentioned; but apparently has the same general strike as the others.

The country rock is part sedimentary, part eruptive; the eruptive masses being frequently intruded between the sedimentary beds. The veins cut through both varieties of rock, passing from one to the other without any apparent interruption. These rocks are cut across by younger eruptives—porphyrys, etc.—which are of frequent occurrence and are probably the cause of the fissuring of the older rocks.

As the district has been studied during the past summer by Mr. Whitman Cross of the United States Geological Survey, and as his report will shortly appear, no attempt will be made at pres-

ent to diagnose these rocks, and those interested in the subject are referred to Mr. Cross' report when it appears.

On the west bank of La Plata River the gangue matter of the veins is of a reddish—often yellowish—color, and near the surface is comparatively soft. Through this gangue occur seams and irregular masses of quartz which carries the telluride minerals. Very small amounts of precious metals are found in the gangue outside of the quartz seams. These quartz seams vary from two inches to six and eight inches in width, and are often very rich in tellurides of gold. Although these tellurides are distributed throughout the quartz, they can at present only be profitably worked at certain points where an enrichment and enlargement of the quartz has taken place. A number of such ore-chutes have been found, and those which have been worked have yielded considerable amounts of gold. These ore-chutes appear to be more or less leached out at or near the surface, and it is not until they have been exploited to a sufficient depth to get away from the oxidizing influences of surface waters that their true value is disclosed.

The quartz which carries the best values is of a dark-grayish appearance, with a greenish cast. When placed in a muffle and heated the gold globules appear on the surface of the specimen. Some of these globules have a gold-yellow color, and others show a greenish, yellow exterior. Associated with the tellurides are pyrite, sphalerite and some copper minerals.

A number of specimens of ore from this district, as well as of the country rock enclosing the veins, were exhibited, illustrating many interesting features of these occurrences of telluride ore.

Some questions being asked by members present as to the direction of the ore-chutes, and as to the enrichment of veins in general where they intersect, an interesting discussion of these subjects took place.

## DISCUSSION.

**Mr. E. B. Kirby** said: Much remains to be learned about ore-chutes; but it seems to me that their genesis and general peculiarities are now pretty well established. All my experience, without exception, confirms the now accepted theory that ore-chutes mark the freest, and, therefore, the main channels followed by the upward flowing mineral solutions. It naturally follows that chutes are most likely to have a steep trend, to be more or less parallel, and to be separated by wider belts of barren vein area.

With regard to ore bodies at the intersection of veins, my own observation is, that outside of special districts, the position of an ore-chute is not generally influenced by an intersection. It depends upon the genesis of the ore deposit, but sometimes this is such as to make intersections important. I will sketch upon the blackboard two interesting cases which I had occasion to examine. In the first case, a main north and south fissure was cut by a cross fissure which faulted it slightly, say one or two feet. This pinched, or dammed up the main fissure along the line of intersection which had a south trend in the fissure. The rising mineral currents were stopped at the under side of this inclined line and then followed it up to the surface, making an ore-chute along the line.

In the second case, an ore-chute in a fissure vein was followed down about eighty feet, yielding \$15,000 or \$20,000. It then disappeared, and thousands of dollars were wasted in deep levels, cross-cuts, etc., all of which failed to find its continuation beneath. Finally a cross-cut into one wall of the old stope disclosed a small cross fissure hitherto unnoticed, and the ore-chute was found to continue its descent within this cross fissure and to be as large and rich as ever. Here we have the interesting case of an ore-depositing current which has risen in one fissure and then changed over to a second fissure lying at right-angles with the first.

**Mr. Regis Chauvenet** called attention to the interesting fact

that in several cases which had come to his knowledge, where two veins crossed, the minerals occurring in one of the crossing veins were all crystallized in forms of the tesseral system, whereas the crystals found in the other vein were wholly of other systems.



## SOME NEW MEXICO COPPER DEPOSITS.

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By W. L. AUSTIN.

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Meeting of December 30, 1897.

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The deposits which are to be briefly described, lie in Mora County, New Mexico, in a small valley about thirty miles northwest of the station of Watrous, on the Santa Fe Railroad, and about one and one-half miles southeast from the village of Guadalupe.

The beds which contain the copper minerals form part of a stratified formation—tipped up on edge—stretching out along the valley for over seven miles in a northerly and southerly direction.

These beds consist of alternating carbonaceous shales, sandstones, sandstone conglomerates and arenaceous limestones. The bedding is remarkably regular, being disturbed by no faults of consequence, the outcrops running along the valley in bold, straight lines for nearly its entire length. At both ends of the valley "malpais" covers these outcroppings; but they appear again on the other side of these eruptive masses, continuing their courses undisturbed.

The copper minerals are, as far as could be observed, confined wholly to the shales. This is an important point in determining the origin of the deposits, and, thereby, their economic value.

The sandstone palisades which form the eastern boundary of the valley for its entire length appear to rest unconformably on the tilted beds.

These palisades rise a thousand feet above the valley at its northern end, diminishing in height towards the south.

An interesting feature in connection with the geology of this valley is the masses of malpais which are found at both ends of it. This malpais forms table mountains, and also flowed over the surface of the sandstone mesa back of the palisades.

As already stated, it covers the beds containing the copper minerals at both ends of the valley. As far as could be observed the malpais eruptions have had little to do with the tilting of these beds, or with the deposition of the copper contained in them.

Copper minerals are found in the beds of shale at various points along the western side of the valley. At or near the surface these beds show only traces of copper, but with a few feet of depth the green—and blue—carbonates appear, and with increasing depth these are replaced by copper sulphides. The carbonates are evidently the result of the decomposition of the sulphides, and often take the forms of the latter, which will be more particularly described further down.

There are several of these beds within short distances of each other, separated mostly by sandstones.

As a usual thing ore-bodies may be accounted for as the production of mineral springs. This theory of formation is, however, inadmissible in this case, because, as these carbonaceous shales consist of a hardened, plastic clay which falls to an unctuous, dark-colored mud upon being placed in water, and as these shales are interbedded with coarse and fine sandstones, and limestones, it is exceedingly improbable that mineral waters emanating from below would have been able to force their way up through material of this class; and especially is it unlikely that they would have selected such a passage-way when the easily soluble limestones and porous sandstones—the latter more or less fissured—offered a more suitable channel. The same kind of clay of which these shale-beds were formed is used to puddle dams with, because of the quality it possesses of rendering such structures water-

tight, and these shale-beds may be regarded as so many natural dams.

That surface waters have not been able to penetrate these shale-beds any distance is shown by their whole appearance, and by the fact that the copper sulphides in the interior of the beds are undecomposed for some distance above water-level. Furthermore, the water found in the workings does not emanate from the shale-beds themselves, but gushes out from seams in the enclosing sandstone.

The shale is almost impenetrable to water, and if copper minerals had been deposited from spring waters they would have found their resting-place in the limestones and sandstones, and not in the shales.

An absurd theory which aims to account for these deposits by assuming that molten copper sulphides were injected into the clay seams from below, is locally current, but it is not worthy of discussion.

Without having recourse to the marvelous, if one will examine these beds with care, and with due consideration for the operations of the forces of nature which may be observed upon all sides at the present day, the origin of these deposits can be accounted for in a very simple manner.

In looking over the district the following facts will be noted: In the first place, these beds consist of sandstone, sandstone conglomerates, shales and lime rock, no igneous rocks were anywhere observed, except the malpais already mentioned.

In the second place, the beds are remarkably regular, extending for miles without a break of any consequence.

In the third place, the shales contain numerous impressions of organic remains, tree trunks, ferns, and irregular shapes—not determined—which have been, to a great extent, converted into sulphide of copper.

In the fourth place, no copper sulphide was observed in the adjoining sandstone and lime rock.

It is, therefore, probable that, back in carboniferous ages, there

existed on this spot an extended shore-line. It might have been a lake or bayou, or lagoon; such as may to-day be seen along the Orinoco River, where small lakes or lagoons, reaching back from the river—of considerable extent, but shallow—are rank with tropical vegetation and the abode of alligators.

These waters are suitable for the growth of fern trees, the remains of which can now be found all through the shales. Into this lagoon, or possibly estuary, a stream emptied. It was a stream of considerable size, because it created a current in the lagoon, and brought down logs, which, passing over the muddy sediment, left grooves in its surface. The current was sufficiently strong to give a general direction to the drift carried into the lagoon.

In some manner—possibly through the medium of some stream flowing over a mass of cuprous pyrite and emptying into the bayou—a solution of sulphate of copper was introduced into its waters, and this solution was gradually decomposed by the organic matter deposited with the sediment. Thus the sulphate was converted into copper sulphide, and this later assumed the shapes and appearances of the organic remains which it replaced. To-day we find the sulphide of copper imbedded in the shales, exhibiting the forms of the old carboniferous flora and fauna. There are even log-jams, the former logs now being converted, to a great extent, into copper sulphide.

As to the reoccurrence of the shale-beds, the fact that they do reoccur may be accounted for in several ways: There may have been an elevation and subsequent subsidence of the land at re-occurring periods; or the phenomenon may be ascribed to other causes.

It is to be expected that surface waters, acting through the long ages since these beds were formed, would have penetrated these measures to a greater or less extent, and in doing so they would necessarily have leached out the copper sulphide and have redeposited it lower down in the form of carbonates, or even in the form of sulphide, the secondary sulphate being decomposed again

by the organic matter remaining in the shale. In the later case fantastic shapes might originate, taking the form of the channels through which the waters percolated. For this reason it is to be expected that the shales near the surface do not contain the amount of copper which they originally held.

But where the shales are fresh, and show no evidences of being subjected to percolating waters, it may be assumed that their copper contents are very nearly intact.

In the existing workings above water level there is very little copper exposed, not sufficient to warrant the working of the deposits, and unless it is reasonable to expect richer ore at greater depths, these deposits are of no present commercial value.

# THE OCCURRENCE OF RHODOCROSITE IN THE "ORIGINAL MINE," BUTTE, MONTANA.

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BY RICHARD PEARCE.

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Meeting of January 3, 1898.

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The mineral presented to the Society was found in the breast of the 1,000-foot level of the claim known as the "Original," which was the first claim located in the Butte district. The "Original" is an eastern extension of the Gagnon, Original Butte and Caledonia claims, forming a group of mines which have produced large quantities of copper and silver.

Rhodocrosite is intimately associated with the silver ores proper, which is found in a distinct and separate system of veins from the copper lodes of the district, and this occurrence of the mineral in the copper group is the first instance that has come under my notice.

The great original vein has been explored to a depth of 1,600 feet, but not a trace of a manganese mineral has been discovered, except one or two very small crystals of huebnerite, which came under my notice some years ago.

The copper minerals associated with the rhodocrosite are bornite, tennantite and enargite.

# AN OLIVINITE DIKE OF THE MAGNOLIA DISTRICT AND THE ASSOCIATED PICROTITANITE.

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By MILTON C. WHITAKER.

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Meeting of February 5, 1898.

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## PART I.—THE OLIVINITE.

### INTRODUCTION.

About two and one-half miles southwest of the University of Colorado, and slightly south of the fortieth parallel, a large outcrop of volcanic rock cuts the granite. Specimens of the same material have been brought to the University Laboratory from as far west as Magnolia, and outcroppings are reported at various intermediate places. This would give the dike a general direction of east and west, and a length, as far as known, of some six or eight miles. Although the material examined was from the most easterly known outcrop, it seems better to refer the whole dike to the Magnolia district.

Our attention was first called to the rock by prospectors, and specimens were sent into the laboratory from various sources. The most striking feature of the rock is the occurrence of irregular nodules, varying in size from a pin-head to an olive, with an anthracite-black color, occurring throughout the mass. The dike has been "located" at various different times, and more or less work has been done at the contact between the eruptive rock and the country granite.

About the first of June I visited the outcrop southwest of the

University, for the purpose of obtaining specimens and samples of both rock and mineral for examination and analysis. This outcrop covers several hundred square yards and is thickly covered with vegetation,\* contrasting it strongly with the surrounding country and making it conspicuous at some distance.

The surface shows a clear dividing line between the dike and the country granite. The granite, which shows a high percentage of feldspar, is crumbled in decomposition. A prospect hole, showing up the line of contact for some ten feet below the surface, gives a fair chance to study the evidences of extrusion and contact alteration; but beyond an indication of slight fusion there is no strong appearance of metamorphism due to the action of the molten magma. A few masses of granite may be found completely enclosed by the eruptive material. The feldspar in such modules is almost completely disintegrated and washed out, while the quartz, mica, etc., remains intact.

#### THE MACROSCOPIC EXAMINATION.

The rock appears in three principal varieties, viz.:

*The first variety.*—Dark-gray to purplish, fracture subconchoidal to hackley. It contains many nodules of serpentine, picrotitanite, chlorite and calcite, varieties of mica, inclusions of apparently foreign garnets usually very fresh, and an occasional fresh crystal of olivine. Besides these, there is to be observed the frequent occurrence of a yellow mineral which I assumed to be some zeolite, which would explain the high percentage of alkalies and water by the analyses.

The specific gravity of this variety is 2.73 as determined by direct displacement. This variety, being more common and ap-

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\*The luxuriant vegetation I attributed at the time to phosphates in the decomposing rock; but the analysis shows such a small percentage of phosphoric anhydride that some other explanation must be offered. Chas. E. Walt, in *The Journal of the American Chemical Society*, Vol. XVIII, p. 402, refers to the occurrence of titanium in the ashes of plants, and this suggests to me a line of investigation to be carried out on the vegetation, which I hope to present to the Society in the near future.



parently the least decomposed, was the one used for analysis and microscopic examination.

*The second variety.*—Dark-purplish to greenish-gray in color, containing much less phenocrystalline material and much more calcite. The other constituents are essentially the same as in the first variety. This variety appears to be much more decomposed than the first variety.

*The third variety.*—Reddish in color, and containing many nodules of a soft, earthy, jasper-red substance, some green serpentine or nodules of green chlorite (apparently an extended alteration of the olivine-serpentine products) with calcite. The other minerals are essentially the same as in the first variety.

When exposed to the weather all varieties have changed on the surface to a light gray, forming a strongly contrasted background for the black, lustrous, undecomposed picrotitanite.

In this connection, it may be noted that titanium minerals, such as sphene and titaniferous magnetite, are of common occurrence in the prominent eruptive rocks of this county, as in the Sugar Loaf andesite, the diorite-like rock of Caribou, the volcanic rock of Alum Hill and elsewhere.\*

Titanium is also reported by President Regis Chauvenet† as occurring in the large iron deposits of Caribou.

#### THE MICROSCOPIC EXAMINATION.

A section of the first variety shows under the microscope many nodules of a serpentinous material, magnetite, and, as in the hand specimens, picrotitanite, garnets, calcite with chlorite, biotite, muscovite, and the zeolitic material.

*The Serpentinous Nodules.*—These consist mostly of characteristicropy, knotted serpentine, interspersed with layers of calcite. These materials surround still smaller nodules of the original undecomposed olivine. Many of the serpentine nodules

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\*C. Irving Andrews' paper, presented to this Society, June 3, 1895.

†*Biennial Report of the State School of Mines*, Golden, Colo., 1886, p. 16.

still show a clear resemblance to the original crystalline form of the olivine. This serpentine also contains, at intervals, small patches of chloritic mineral grouped in the peculiar variolite structure.

*The Magnetite.*—This occurs apparently well crystallized and appears to make up about one-third of the ground-mass; but the figures of the analysis and the specific gravity determination of the rock do not bear out this estimate; and, therefore, it is probable that some of this apparent magnetite is some decomposition product coated with magnetite. Another section shows very much less magnetite.

*The Picrotitanite.*—This appears to be not at all decomposed, usually opaque, but in one case showing a brownish translucency. It seems to be in well defined, coarse nodules, and does not appear in fine particles in the ground-mass. This observation is also supported by the small amount of titanium shown in the analysis of the rock, care being taken in the choice of samples for analysis, to avoid the larger nodules of picrotitanite.

*The Garnet.*—This mineral occurs sparingly in a light pink variety, usually very fresh and transparent, but in some cases showing the beginning of decomposition. The characteristic garnet of an olivine bearing rock is *pyrope*,\* but some further work will be necessary to identify positively the variety of this dike. The body of those garnets which are partly decomposed, shows many fissures filled with calcite and the zeolitic material. Externally these decomposed garnets show a kelyphite rim structure, but the decomposition of this rim is probably an opaque ferruginous mineral with calcite and zolite instead of the pyroxene-amphibole needles of a true kelyphite.†

*The Calcite.*—This appears as the characteristic silver-white cryptocrystalline variety throughout the ground-mass, with an occasional phenocryst interpenetrated by chlorite.

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\*Zirkel, *Lehrbuch der Petrographie*, Vol. I, p. 366.

†Zirkel, *Lehrbuch der Petrographie*, Vol. I, p. 366.

*The Chlorite.*—This occurs rather infrequently, and in irregular greenish bands throughout the section.

*The Micas*—Sparingly, nodules of both light and dark varieties, and in some cases surrounded by ferruginous alteration bands.

The mineral which bears a resemblance to zolite, and which is also suggested by the analysis, occurs in irregular distribution throughout the ground-mass.

Taken as a whole, the present appearance of the rock suggests an alteration from an original, which was probably essentially an olivinite, with porphyritic phenocrysts imbedded in a hypocrystalline ground-mass containing smaller crystals of olivine of a second generation.

#### ANALYSES.

The samples for these analyses were taken from the more common and least decomposed variety of the rock described as "the first variety." Care was taken to avoid using any particles of either picrotitanite or garnet. Otherwise the samples were chosen at random.

Ferrous iron and the alkalies were determined in separate portions for both analyses. The carbon dioxide was determined by direct absorption by potassium hydroxide. The water was determined by direct absorption by sulphuric acid. The phosphoric anhydride was precipitated as the phospho-molybdate, redissolved and ultimately weighed as magnesium pyrophosphate. The titanium dioxide was determined as the residue, after evaporating off the silica as silicon-tetra-fluoride.

The results of the analyses are tabulated below.

## ANALYSIS A. (Rock.)

	<i>I.</i>	<i>II.</i>	<i>III.</i>	<i>IV.</i>	<i>V.</i>	<i>VI.</i>
SiO <sub>2</sub> .....	22.24	.....	.....	.....	.....	.....
TiO <sub>2</sub> .....	0.36	.....	.....	.....	.....	.....
P <sub>2</sub> O <sub>5</sub> .....	.....	0.61	.....	.....	.....	.....
CO <sub>2</sub> .....	.....	.....	8.79	.....	.....	.....
Al <sub>2</sub> O <sub>3</sub> .....	11.78	.....	.....	.....	.....	.....
Fe <sub>2</sub> O <sub>3</sub> .....	4.74	.....	.....	.....	.....	.....
FeO .....	.....	.....	.....	3.35 ( <i>a</i> )	.....	.....
CaO .....	10.19	.....	.....	.....	.....	.....
MgO .....	25.00	.....	.....	.....	.....	.....
K <sub>2</sub> O .....	.....	.....	.....	.....	3.64 ( <i>a</i> )	.....
Na <sub>2</sub> O .....	.....	.....	.....	.....	3.29 ( <i>a</i> )	.....
H <sub>2</sub> O .....	.....	.....	.....	.....	.....	5.63

The figures marked (*a*) are averages of several determinations and quoted in both analysis A, and analysis B.

## SUMMATION OF ANALYSIS A. (Rock.)

Silica .....	22.24
Titanium dioxide .....	0.36
Phosphoric anhydride .....	0.61
Carbon dioxide .....	8.79
Alumina .....	11.78
Ferric oxide .....	4.74
Ferrous oxide .....	3.35
Calcium oxide .....	10.19
Magnesia .....	25.00
Potassium oxide .....	3.64
Sodium oxide .....	3.29
Water .....	5.63
	<hr/> 99.62

## ANALYSIS B. (Rock.)

	<i>I.</i>	<i>II.</i>	<i>III.</i>	<i>IV.</i>	<i>V.</i>	<i>VI.</i>
SiO <sub>2</sub> .....	21.90	.....	.....	.....	.....	.....
TiO <sub>2</sub> .....	0.32	.....	.....	.....	.....	.....
P <sub>2</sub> O <sub>5</sub> .....	.....	0.58	.....	.....	.....	.....
CO <sub>2</sub> .....	.....	.....	8.75	.....	.....	.....
Al <sub>2</sub> O <sub>3</sub> .....	11.95	.....	.....	.....	.....	.....
Fe <sub>2</sub> O <sub>3</sub> .....	4.60	.....	.....	.....	.....	.....
FeO .....	.....	.....	.....	3.35 ( <i>a</i> )	.....	.....
CaO .....	10.77	.....	.....	.....	.....	.....
MgO .....	25.78	.....	.....	.....	.....	.....
K <sub>2</sub> O .....	.....	.....	.....	.....	3.64 ( <i>a</i> )	.....
Na <sub>2</sub> O .....	.....	.....	.....	.....	3.29 ( <i>a</i> )	.....
H <sub>2</sub> O .....	.....	.....	.....	.....	.....	5.59

The figures marked (*a*) are averages of several determinations and quoted in both analysis A, and analysis B.

## SUMMATION OF ANALYSIS B. (Rock.)

Silica .....	21.90
Titanium dioxide .....	0.32
Phosphoric anhydride .....	0.58
Carbon dioxide .....	8.75
Alumina .....	11.95
Ferric oxide .....	4.60
Ferrous oxide .....	3.35
Calcium oxide .....	10.77
Magnesia .....	25.78
Potassium oxide .....	3.64
Sodium oxide .....	3.29
Water .....	5.59
	<hr/> 100.52

In a rock as highly decomposed as this, it is almost impossible to match the acids and bases with any degree of certainty; but some suggestions regarding the presumable distribution may not be out of place.

The most striking features of the figures of these analyses are the low percentages of silica, and the relatively high percentages of magnesia, carbon dioxide and the alkalies, respectively; and in detail:—

*Firstly.* The carbon dioxide and lime approximately balance each other.

*Secondly.* The average composition of serpentine accounts fairly well for the silica, the magnesia, some of the ferrous oxide and some of the water.

*Thirdly.* Zeolites are suggested by the alumina, the alkalies and the excess of silica.

*Fourthly.* Accounting for the ferrous and ferric iron as magnetite, an excess of ferrous iron is left, which can easily be accredited to either chlorite or serpentine.

But it seems impossible to account for the exact distribution of acids and bases by any or all of these suppositions. Incidentally, the high percentages of sodium and potassium oxides, with the alumina, may possibly be explained by considering them as derived from the decomposition of the feldspars of the country granite, many nodules of which, as we have seen, are enclosed bodily in the eruptive rock and show almost complete disintegration of the feldspar, the quartz and other constituents being undecomposed.

#### PART II.—THE PICROTITANITE OR MAGNESIAN MENACCANITE.

The appearance of the conspicuous black nodules of this mineral in the dike offered the leading motive for the examination of the altered olivine rock. The mineral is interesting, not only as offering a new occurrence of the high magnesian variety of ilmenite, but also as being the first recorded occurrence of the mineral in Colorado. Dana's Mineralogy (*last edition*, p.

217 219,) mentions only two localities, viz.: South Africa, and Warwick, N. Y., as furnishing an ilmenite of a higher percentage of magnesia. I take the liberty to quote these analyses for comparison later on.

#### THE ANALYSES.

The qualitative analysis of the mineral gave titanium, ferrous iron, ferric iron, magnesia, silica and water. It had been reported that the mineral contained small percentages of thorium and cerium, but I was unable to distinguish either of these elements.

The quantitative analysis of this mineral offers to the beginner many difficulties; such as the difficult solubility, the fact that it is a titanium mineral, and the apparent impossibility of getting at all the ferrous iron. The mineral is soluble in acid-potassium-sulphate with long-continued fusion, and is also soluble in a mixture of hydrofluoric, sulphuric and hydrochloric acids. I will give an outline of the methods used, in the hope that some suggestions and improvements may be offered which will enable one to arrive at better results.

#### FIRST METHOD.

*Mineral Dissolved in Acid-Potassium-Sulphate.*—About one gram of the finely-powdered mineral is added to a previously-fused mass of about ten grams of acid-potassium-sulphate. Decomposition usually takes place after about forty-five minutes, at a dull red heat. After cooling it is transferred to a tumbler, and hydrochloric acid (dil. 1:1) is added. With frequent crushing and stirring of the mass, solution will require about one hour. It is then filtered into a beaker, and the silica is determined in the residue, by difference, on evaporating to a constant weight with hydrofluoric and sulphuric acids. The residue, if any, after this operation, is again fused with acid-potassium-sulphate, dissolved, and added to the original solution in the beaker. Ammonium hydroxide is now added in excess and the mixture boiled till the

smell of ammonia is no longer noticeable. It is then filtered and washed with hot water containing ammonia until free from sulphuric acid. The filtrate must be concentrated and saved for the determination of the magnesium, although it is found that almost all the magnesium has temporarily accompanied the precipitated iron and titanium hydroxides.

The precipitate is now dissolved in hydrochloric acid (dil. 1:1)\* and the paper thoroughly washed. The hydrochloric acid solution is neutralized with ammonium hydroxide, as far as possible, without reprecipitating the iron or titanium; strong sulphurous acid is added, and the solution warmed slowly till it becomes colorless. The solution is then heated to boiling, and this maintained for about two hours, keeping an excess of sulphurous acid present. The titanium is precipitated perfectly white, finely granular, and is easily filtered. It must be filtered while hot, and the first portions of the filtrate may need to be put through the paper again, but the final filtrate is clear. The precipitate must be washed with hot water containing sulphurous acid. The titanic acid is dried and weighed as titanium dioxide, and gives tests of only *the merest traces of iron, and no magnesium*. The filtrate is concentrated, and the iron oxidized with nitric acid and determined as ferric oxide in the usual manner. The magnesia is determined as magnesium pyro-phosphate, after mixing with the filtrate from the first precipitation of the mixed hydroxides.

#### SECOND METHOD.

*Mineral Dissolved in Hydrofluoric, Sulphuric and Hydrochloric Acids.*—The finely-powdered mineral is treated with hydrofluoric acid and is heated until the black powder is completely disintegrated. Sulphuric acid is then added and it is evaporated to dryness to free from hydrochloric acid.† Dilute

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\*Chas. E. Baskerville. *Journal of the American Chemical Society*, Vol. XVI, p. 427.

†Of course, great care must be taken to completely free from hydrofluoric acid to avoid error by dissolution of the glass vessels in subsequent operations.



sulphuric acid is then added and the residue is washed from the platinum dish into a beaker containing hot hydrochloric acid. After warming and stirring for a few moments, solution will be complete. From this point the process of analysis is the same as for the method of decomposition with acid-potassium-sulphate.

The results of one analysis by the latter method of decomposition, and two by the former, are quoted below.

The specific gravity of the mineral is 4.43 to 4.45.

## ANALYSIS C. (Hydrofluoric Acid Method.)

	<i>I.</i>	<i>II.</i>	<i>III.</i>	<i>IV.</i>	<i>Total.</i>
TiO <sub>2</sub> .....	52·321 ( <i>a</i> )	.....	.....	.....	53·321
Fe <sub>2</sub> O <sub>3</sub> .....	12·817	.....	.....	.....	12·817
FeO .....	.....	23·704 ( <i>b</i> )	.....	.....	23·704
MgO .....	11·623	.....	.....	.....	11·623
SiO <sub>2</sub> .....	.....	.....	0·535	.....	0·535
H <sub>2</sub> O .....	.....	.....	.....	0·498 ( <i>c</i> )	0·498
					101·498

(*a*). An average of two determinations by the same method.

(*b*). An average of three determinations and quoted in analyses C, D and E.

(*c*). An average of two determinations and quoted in analyses C, D and E.

## ANALYSIS D. (Acid-Potassium-Sulphate Method.)

	<i>I.</i>	<i>II.</i>	<i>III.</i>	<i>IV.</i>	<i>Total.</i>
TiO <sub>2</sub> .....	52·506	.....	.....	.....	52·506
Fe <sub>2</sub> O <sub>3</sub> .....	12·243	.....	.....	.....	12·243
FeO .....	.....	23·704 ( <i>a</i> )	.....	.....	23·704
MgO .....	12·204	.....	.....	.....	12·204
H <sub>2</sub> O .....	.....	.....	.....	0·498 ( <i>b</i> )	0·498
SiO <sub>2</sub> .....	.....	.....	0·534	.....	0·534
					101·689

(*a*) Average of three determinations and quoted in analyses C, D and E.

(*b*) Average of two determinations and quoted in analyses C, D and E.

## ANALYSIS E. (Acid-Potassium-Sulphate Method.)

	I.	II.	III.	IV.	Total.
TiO <sub>2</sub> .....	50·942	.....	.....	.....	50·942
Fe <sub>2</sub> O <sub>3</sub> .....	13·418	.....	.....	.....	13·418
FeO .....	.....	23·704 (a)	.....	.....	23·704
MgO .....	12·342	.....	.....	.....	12·342
SiO <sub>2</sub> .....	.....	.....	.....	0·534 (b)	0·534
H <sub>2</sub> O .....	.....	.....	0·498 (c)	.....	0·498
					101·438

(a) Average of three determinations and quoted in analyses C, D and E.

(b) Average of two former determinations and quoted in this analysis, E, only

(c) Average of two determinations and quoted in analyses C, D and E.

## CALCULATIONS OF THE MOLECULAR RATIO, FROM AN AVERAGE OF THE ABOVE ANALYSES, C, D AND E.

	Per Cent. M. W.	Ratio.
TiO <sub>2</sub> .....	51·923 + 80 = 649	2·15
Fe <sub>2</sub> O <sub>3</sub> .....	12·825 + 160 = 1080	0·23
FeO .....	23·704 + 72 = 329	1·09
MgO .....	12·056 + 40 = 301	10·0
SiO <sub>2</sub> .....	0·535	
H <sub>2</sub> O .....	0·498	
	101·541	

From the above ratio we derive the approximate formula, MgO, FeO, 2TiO<sub>2</sub>. For discussion on the composition of a variety of ilmenite quite similar to this, see article by Penfield and Foote, (*Amer. Jour. Science*, Vol. IV, p. 108).

COMPARISON OF ANALYSIS OF THREE VARIETIES OF MAGNESIAN  
ILMENITE.

I. Warwick, N. Y. Penfield and Foote (*Amer. Journal of Science*, Vol. II, p. 108).

II. Du Toit's Pan, South Africa (*Dana's Mineralogy*, p. 219, analysis by Cohen).

III. Boulder County variety.

	I.	II.	III
	<i>Penfield and Foote.</i>	<i>Cohen.</i>	<i>Whitaker.</i>
TiO <sub>2</sub> .....	57.29	53.79	51.92
Fe <sub>2</sub> O <sub>3</sub> .....	1.87	7.05	12.82
FeO .....	24.15	27.05	23.70
MgO .....	15.97	12.10	12.05
SiO <sub>2</sub> .....	0.37	.....	0.53
H <sub>2</sub> O .....	.....	.....	0.49
MnO .....	1.10	.....	.....
	<hr/> 100.75	<hr/> 99.99	<hr/> 101.51
S. G .....	4.34	4.43	4.44

A great deal of trouble was experienced in determining the ferrous oxide in this mineral, and I am inclined to believe that most of the persistent error in these analyses is due to my inability to get the correct figures for ferrous oxide.\*

By decomposing the mineral with hydrofluoric acid, adding sulphuric acid, and titrating with potassium permanganate, I obtained in two operations 11.71 per cent. and 11.81 per cent. respectively for ferrous oxide. Afterwards, by decomposing the mineral in hydrofluoric, sulphuric, and hydrochloric acids after the methods described in the analysis, and titrating with a standard solution of potassium bichromate, I obtained successive results respectively of 21.47 per cent. and 21.38 per cent. for ferrous oxide; but these results were both rejected on account of

\*Immersion in an acid solution of copper sulphate gave negative tests for native iron.

rather incomplete solution of the mineral. In three later and more satisfactory operations by the same method, the respective results were: 23.894—23.425—23.794 per cent. of ferrous oxide, giving an average of 23.704 per cent. (The last of these results was obtained after decomposing and titrating in an atmosphere of carbon dioxide.)

This average of 23.704 per cent. for ferrous oxide gives the figures quoted in my analyses; but that these figures are still too low for ferrous oxide is indicated by the gain the mineral showed on being heated to a constant weight (taking the water into account); and this is also supported by the fact that the totals of the analyses are 1.5 per cent. too high.

If the results for ferrous oxide were corrected by the calculations from the figures obtained by heating the mineral to a constant weight the average totals would be reduced by about 0.5 per cent.

After some very annoying experiences in the precipitation and determination of titanium in such large amounts as in minerals of this kind, I find the suggestion of Mr. Baskerville (*loc. cit.*) of the greatest importance, viz.: in precipitating from a *hydrochloric acid solution* the precipitate is perfectly white, contains only the slightest traces of iron, is granular and easily filtered and washed, does not stick to the glass, and does not require great dilution for complete precipitation. In my experience the reverse of all this is true in the precipitation of titanium from sulphuric acid solutions. Moreover, to add sodium acetate and acetic acid to a hydrochloric acid solution before precipitation, as we are usually directed to do in a sulphuric acid solution, is entirely detrimental, as it produces an impure flocculent precipitate, which is hard to filter and wash, and which must be re-fused and re-precipitated before weighing.

This paper may be regarded as one of the series of papers issued from the laboratory of the State University on the "Eruptive Rocks of Boulder County."

In closing, I wish to acknowledge my indebtedness to Prof. Chas. S. Palmer for valuable suggestions and assistance in the work presented here.

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*Note.*—Since the article was sent to the printer, my attention was called to an article by J. S. Diller (*Bulletin U. S. Geological Survey*), on "The Periodotite of Elliott County, Kentucky," which bears a very close resemblance, both in the rock and in the ilmenite, to the material from the Magnolia Dike.

NOTE ON THE OCCURRENCE OF CARBONIC ACID  
GAS IN CERTAIN VEINS OF GILPIN  
COUNTY, COLORADO.

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By ARTHUR L. COLLINS.

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Meeting of February 5, 1898.

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In the spring of 1896, two men lost their lives by suffocation in the Brooklyn Mine, near Central City. They were the first of the shift to be lowered in the bucket, the other shift having blasted and left the mine nearly two hours previously. As no signal came from the bottom, men were sent down to investigate. The workings were found to be full of gas, for which the mine had always a bad reputation, but after considerable difficulty and delay the two dead bodies were found a few feet within the bottom level, some 140 feet from the surface.

An examination of the workings on the day following the accident showed that it was impossible to keep a light below about eighty feet deep; the line between good air and bad being so sharp that ascending two rungs of the ladder enabled the extinguished candle to be relit. A similar sharp boundary was observed at the east level at this depth, where a candle could be easily carried breast-high, but was extinguished when lowered within two feet of the ground. In a sheltered corner the line could be found so closely that the expiring bluish flame could be kept hovering over the candle-wick for an appreciable time. It should be added that work at the mine had been entirely stopped over night.

The gas had no appreciable taste nor smell, and beyond a slight drowsiness, no effects were noticed from breathing it in con-

siderable quantities. There was nothing akin to the acute headache caused by dynamite smoke, or the sickness and dizziness often following a stay in an overcrowded and ill-ventilated "raise." The exhaustion of very little of the gas through lime-water caused well marked milkiness, showing that carbonic acid gas constituted part at least of its volume.

Suggested by the similar practice in coal mining, note was taken of the barometer and state of the weather for the next month. The barometer was unusually low on the day of the disaster, 20.28, and remained so for three days until April 5, when it rose in the afternoon to 20.40, and the workings were first freed from gas by the ventilating stove and fan which had been kept steadily going for two days. For the next few days the barometer rose pretty steadily to 20.80, and the air underground regained its normal excellence. On the 12th it stood at 21.00, the highest noted for the month, and for the next twelve days it fluctuated between 20.85 and 20.60, with no gas noted. On the 24th a sudden fall from 20.85 to 20.70 coincided with a slight emanation underground; but this disappeared next day, the barometer remaining close to 20.70 until the 29th. On the 30th it fell to 20.44. Gas appeared in the mine so strongly as to stop all work, in spite of fan and stove, and it was not until May 4, when the barometer rose once more to 20.55, that work could be resumed.

These coincidences were confirmed under repeated tests. No connection could be observed between outside temperature, or direction and force of wind, and the state of the air underground; but there is no room for doubt that a low barometer, or a sudden fall, coincides with the "bad air" in the mine.

It should be added that the readings were only taken with an aneroid and are therefore only relatively correct; and that the elevation of the shaft-house above sea-level is about 8,750 feet.

Emanations of similar gas have since been noticed in driving from the Bobtail Tunnel along the Mammoth vein. Here the gas has whistled out of small "vughs" in the vein, after blasting, with sufficient force to blow out a candle a foot away.



Carbonic acid is well-known to exude from coal, and Professor Foster mentions several lead mines in France and Great Britain where it has been noticed.\* But its presence in Gilpin County veins, among crystalline archaen gneisses and granites, is more difficult to explain. The Brooklyn and Mammoth veins are both wide, and carry large bodies of coarsely crystallized iron pyrites, which, in places, form half the weight of the vein contents for widths of several feet; the balance being quartz and kaolinized "country." The other sulphides common to the district, chalcopryite, blende or galena, are here quite rare; and calcite, or any carbonate mineral, has not been observed at all. The decrepitation of certain kinds of pyrite has been ascribed to the presence of liquid carbonic acid in its pores and fissures,† and it is noteworthy that much of the pyrites of these veins decrepitates violently when heated in the blowpipe flame.

Other veins where emanations of gas have been heard of, are the Gregory, Fisk, Nottoway (where a man lost his life by suffocation many years ago), and the Justice and Shamrock in the eastern end of the county. It is difficult to trace any system in the localities; there are dozens of veins of iron pyrites as large as the Brooklyn, where the gas is unknown; it is found in veins both in granite and gneiss‡—both near to and far from the porphyry intrusions so common in the district. But it is obvious that in mines where the presence of gas is suspected, daily readings of the barometer should not be neglected by the conscientious mining superintendent. In all such cases, forewarned is forearmed.

#### DISCUSSION.

Mr. E. Le Neve Foster said that this gas had been somewhat troublesome in the Saratoga Mine, and that an attempt to remove

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\*E. Le Neve Foster, "Ore and Stone Mining," p. 475.

†Foster, *loc. cit.*, p. 476.

‡Comp. Hayden's Geol. Survey of Colorado, 1873, map facing p. 280 of F. M. Endlich's report.

it by a strong current of air through a pipe six inches in diameter had failed. He had succeeded in driving it out by introducing a jet of steam into the mine.

**Mr. Arthur L. Collins** said that in all cases that had come to his knowledge, a stove had proven much more effectual than a fan in removing the gas from the workings.

## GAS AND OIL ENGINES.

By THOMAS L. WILKINSON.

Meeting of March 5, 1898.



The gas consumed in one 16 C. P. gas jet, if consumed in a gas engine, will produce three 16 C. P. electric lights.

In the engineering world—especially in that department relating to the development and transmission of energy—methods have been revolutionized, new ideas have been adopted, resulting advantageously; progress has been rapid; it has been, and is continuous, it could not be otherwise.

The owners and users of power are the ones especially interested, or should be, in the manner and method of the production and transmission of energy. As a rule we may safely assert that the shipowner, the manufacturer, or railroad company, care little or nothing for the theoretical questions involved in the construction or operation of their power plants. Their chief want and desire is, to have their coal bills kept as low as possible, and the

smallest consumption of fuel per horse-power per hour. They intrust this to their engineers. And so, in the development and distribution of energy, in the past ten years, the watchword has been *economy*.

In steam engineering every pound of steam gained has its immediate influence on many engine builders of the country. The causes of economy in the steam engine are: steam jackets, compounding, reheaters and high steam pressures, due naturally to the water tube boiler.

Since 1870 the steam consumption of engines has gradually decreased from twenty pounds to ten pounds. The most notable example being the pumping engines at the Milwaukee water works, which, under a three-months' trial returned the result of 11.67 pounds per horse-power per hour. This, however, has been eclipsed by an experimental quadruple expansion engine, built and tested at one of our leading universities, which gave a horse-power on slightly less than ten pounds of steam.

There is little doubt but that the steam engine has reached the limit of perfection. The highest developed steam engine barely reaches an efficiency of 20 per cent.

Twenty-five years ago it was not thought that either steam or water power would have as lively a rival for power purposes as gas and oil engines have developed. But as *economy* has ever been the watchword, inventors have not been idle, for in the last twenty-five years prime movers in the shape of gas and oil engines have been developed to such an extent that they now readily take rank with the best steam engines yet built, if, in point of efficiency, they do not already outrank them. And the reason for this is obvious when results positively show that even at the present time gas and oil engines return an efficiency, that is, a thermal dynamic efficiency, of 30 per cent., thus doing work which can never be expected or hoped for in the steam engine.

Comparing the efficiency of gas with steam power, the following table, prepared some years ago by Köerting, a German engineer,

when the gas engine was not as efficient as at present, will be found to be of much value:

## STEAM ENGINES.

10 horse-power.....	2.2 per cent. useful effort.
50 " " .....	4.6 " " " "
100 " " .....	6.9 " " " "

## ILLUMINATING GAS MOTORS.

10 horse-power.....	9.1 per cent. useful effort
50 " " .....	9.9 " " " "
100 " " .....	10.9 " " " "

## POWER GAS MOTORS.

10 horse-power.....	7.3 per cent. useful effort.
50 " " .....	10.2 " " " "
100 " " .....	12.9 " " " "

It was Beau de Rochas who, in 1862, laid down the axiom in his patent for a gas engine, that no gas engine could be economical unless its cycle included *compression* of the mixture of gas and air after admission to the cylinder.

Previous to this time the consumption in gas engines was extremely extravagant, yet no one even proposed compression until Otto brought out his gas engine, which he patented in 1876. Although it was Beau de Rochas who discovered the correct principle, the honor of having produced the first practical working gas engine, using compression, certainly belongs to the distinguished German engineer, Otto. The original Otto engine appeared at a time when steam was about to drive the gas engine from all competition. It therefore was a great surprise to the engineering world when the Otto gas engine was first successfully operated at the Paris Exposition in 1878. The innovation, as has been said, was the compression of the charge of gas and air in the cylinder before ignition. The inventor himself did not fully understand the value of this compression, but by this he reduced the consumption of gas, and laid his success and the popularity of his engine, not to the compression, but to the stratification, of the charge as it

enters the cylinder. However, this *stratification* theory has long since been exploded.

We may consider this original Otto gas engine so as to compare it with the modern Otto, and note the advancement.

The original type of the Otto gas engine was horizontal, the end of the cylinder nearest the crank being open. In many respects it was, in appearance, not unlike the ordinary steam engine. The cycle is divided into four piston strokes and one impulse, due to the one explosion obtained during these two revolutions. The cycle operates as follows: The first stroke of the piston (nearest the crank) draws in the gas and air, the return stroke compresses it, during the next forward stroke *work* is done on the piston, due to the explosion, and in the fourth or second return stroke, the products of combustion are discharged from the cylinder. The third stroke of the piston is the only one during which work is done, here the explosion occurs, causing the gases to expand, thus forcing out the piston. Only one side of the piston is operated on. The clearance space is unusually large, being about four-tenths of the whole volume of the cylinder. The clearance space being so large the products of combustion are never entirely expelled, and Otto claimed at that time that it was rather an advantage to retain part of the products of combustion to act as a cushion against the piston, and so deaden the shock of the explosion. There being but one impulse in each two revolutions, heavy fly-wheels are required to keep up the momentum. In this first type of the Otto engine, a permanent gas flame was the source of ignition. A slide valve, operated in this connection, which pocketed a part of the flame, after admitting the charge, ignited the charge at the proper time.

The theory of stratification, which was adhered to by many scientific men of the time, is that the slide valve was so constructed that pure air first enters the cylinder, and mixes with the products of combustion which could not be expelled by the piston, as the piston cannot enter the clearance space. So that

"Next to the piston there is said to be a weak mixture which is intended to deaden the shock and retard combustion, and to take up some of the heat developed by the explosion. Gas next enters the slide valve and mixes with the air, and this layer, on reaching the cylinder, forms a dilution of medium strength, the proportions being about seven of air to one of gas. Finally by the movement of the slide valve pure gas alone, without any admixture, is admitted into the cylinder. It is this gas which, through the grooved passage in the slide valve, feeds the burning light, and causes it to shoot into the poorer mixture like a tongue of flame. Thus there are three strata in the cylinder of three different degrees of richness; the mixture nearest the piston being so diluted that it will not ignite, except by the force of the explosion. The flame is supposed to leap from one layer to another, producing the slow combustion so much desired by Otto."

This theory, however, is no longer upheld, and that this theory of stratification is not correct is shown by the fact that all makers of the modern Otto engine have abandoned the slide valve and substituted the lift valve.

Since 1882 great advances have been made in the construction and efficiency of gas engines. The power that they now develop has been very materially increased, so that now, viewed from any standpoint, they show themselves to be highly efficient prime-movers.

Of all the new engines that have found their way into the commercial industries, all are one or the other of three types.

1. Non-compression engines, igniting at constant pressure. (No explosion.)
2. Compression engines, igniting at constant pressure. (No explosion.)
3. Compression engines, igniting at constant volume. (Explosion.)

Of the non-compression gas engines the Lenoir is probably the best type. In the second class there are really two types:

(a) In which ignition is followed by a sudden rise of pressure in a constant volume, such as the new Lenoir, Clerk, Griffin, Fielding, etc., and

(b) In which the mixture is gradually ignited as it enters

the cylinder, expanding at constant pressure in a varying volume, such as the Brayton, Siemens, and Foulis.

For practical purposes the first two types are to be omitted from discussion. Non-compression gas engines are now considered much too wasteful of gas to hold a place as to economy, and compression engines of the second type, that is, compression with ignition at constant pressure, have not advanced beyond the type of Brayton, which consumed at best thirty-two cubic feet of gas per horse-power per hour.

All gas engines now constructed are of the third type or compression of the charge, with ignition at constant volume, when the pressure rises.

One writer, and an authority on gas engines, further subdivides this third type into two others—

(a) Engines working in accordance with the Otto cycle, in which one cylinder fulfils alternately the functions of pump and motor, so that only one impulse may be obtained for the *two* revolutions of the crank shaft.

(b) Engines having a separate pump or other charging device by which a charge is compressed in, or introduced, in a compressed state, into the power cylinder, and *one* impulse may be obtained for *each* revolution of the crank shaft.

This last sub-division or engines igniting at every revolution have not attained the popularity of the engines working on the Otto cycle, which latter have proved, by the test of experience, to be the best adapted of all gas engines yet invented, and they have more than held their own to the extinction of all others.

Compression is the key to gas engine *economy*. From 1882 to 1888 little change in this direction took place in the Otto. The compression never rose above 40 pounds per square inch above atmospheric pressure, and the actual indicated efficiency was about 15 per cent.

In 1888 the results of a test on an eight horse-power Otto, built by Messrs. Crossley, gave a horse-power on a consumption of twenty-two cubic feet of Glasgow gas. The heat evolved from one



cubic foot of Glasgow gas is equivalent to 588,530 foot pounds, at atmospheric pressure and at a temperature of 62° F. Now if all this heat could be converted into mechanical work it would require 3.36 cubic feet of the gas to indicate *one* horse-power for *one* hour. Hence the indicated efficiency of the engine consuming twenty-two cubic feet of gas per one H.-P. hour, would be:

$$E = \frac{3.36}{22} = .15$$

In the fall of the same year a test was made on an Otto of the same firm make, with the following dimensions: Diam. of cylinder 9½ inches, stroke 18 inches. The gas consumption was 20.5 cubic feet per horse-power hour, and the compression 61.6 pounds per square inch above the atmosphere. The indicated horse-power was 17.12 and the brake horse-power 14.74 at 160 revolutions. The heating value of the gas was found by analysis to be 483,270 foot pounds per cubic foot, measured at atmospheric pressure and at 32° F. So that 4.3 cubic feet would be required to furnish heat units equivalent to *one* horse-power per hour. The absolute efficiency was therefore

$$E = \frac{4.3}{20.5} = .21$$

Thus there was obtained a gain in efficiency of 6 per cent. from '82 to '88 and this was due mainly to compression. From '88 to '94 21 per cent. was not exceeded, but in that year an efficiency of 25 per cent. was reached with a gas consumption of 14.8 cubic feet per one H.-P. hour. A point worthy of notice in this test is that the engine was of four horse-power (nominal) and the brake horse power was twelve, which is a surprisingly good result.

With a larger engine an efficiency of 27 per cent. was obtained. This engine was of fourteen nominal horse-power and the cards figured 46.8 horse-power, with a gas consumption of 13.5 cubic feet.

The advance that has been made in gas engines since 1882 has been very marked, as may be seen from the following table:

ABSOLUTE INDICATED EFFICIENCY OF CROSSLEY-OTTO ENGINES OF SIMILAR SIZE SINCE 1882.

	<i>Eff.</i>	<i>Pressure of Compression above Atmos. Press. per Sq. Inch.</i>
1. 1882-'88.....	15	38.0
2. 1888-'94.....	21	61.6
3. 1894.....	27	87.5

It is very evident, then, that economy increases with compression, but to what extent compression may be carried has not been determined by experiment. Clerk considers a compression of 200 pounds per square inch as above the limit to which the Otto may go and be useful. Clerk has calculated

"An ideal case of this kind, in which the pressure of the compression was 100 pounds above the atmosphere and the explosion temperature 2912° F. The theoretical efficiency of such an engine would be 73 per cent."

The actual efficiency would therefore be 43 per cent. This is, however, calculated for an engine of large power, say 200 horsepower.

In the later Otto engines, the bevel wheels which operate the valve mechanism, have been replaced by skew wheels which insure much quieter running for the cam shaft. The method of ignition has been changed, the volume of the compression space has been cut down, and the valves are better proportioned. "Scavenging" the cylinder by means of pure air to rid it of the foul exhaust gases, has also resulted in economy. Scavenging has also in a large measure done away with untimely explosions.

On the larger sizes of all gas engines, from twenty horsepower up, self-starters are provided, on the smaller sizes a few turns of the fly-wheel are sufficient to set the engine in motion. The Otto gas engine made in this country, employs the electric spark as a means of ignition.

Gasoline engines which are now very largely used, have all

the advantages of gas engines, and, with slight modifications, may be operated with gasoline. The provisions for safety are such that insurance companies interpose no objection to their use, even in saw mills, and do not, on account of the gasoline, raise the rate.

While to Otto belongs the honor of having produced the first practical gas engine, the honor of having produced the first successful oil engine belongs to the Messrs. Priestman. This engine was brought out in 1888.

I shall confine myself to but two forms of the oil engine—the Priestman and the Hornsby-Akroyd. These engines are purely oil engines, not gas or gasoline.

In the Priestman oil engine the oil is treated mechanically, it is not gasified, but is atomized by air pressure maintained by the engine, and is burnt within the cylinder in its atomized form, expanding the air and producing power. The amount of oil admitted by the spray maker is readily controlled, and is dependent on the air pressure, and thus the engine is governed on the throttling principle. The lubrication of this engine is done automatically by the atomized kerosene condensing on the sides of the cylinder. The amount of oil consumed in this engine depends upon the amount of work done. The governor is so arranged that the quantities of oil and air are each proportioned to the load carried. As the load increases the oil consumption increases. The amount required is about one and one-half pints per brake horse-power per hour. The electric spark is employed to fire the charge.

The Hornsby-Akroyd oil engine differs from all other gas and oil engines in that it is neither ignited by the hot tube or electric spark, but by

“The spontaneous ignition of the oil vapor, due to its compression, and to the heat of the vaporising chamber. The oil is injected into a hot chamber at the back of the cylinder, into which heated air, compressed by the back stroke of the piston, is forced as it reaches the inner dead point, and the mixture ignites spontaneously.”

The auxiliary cylinder or hot chamber is not water-jacketed, so that it remains at a temperature of a dull red heat. The oil is forced into this chamber in a thin stream by a pump actuated by the same lever that opens the air valve. Now at the end of the first operation we have, first, the cylinder full of pure air; second, the combustion chamber full of oil vapor. Neither of these is alone explosive, but when the pure air is compressed and forced into the hot chamber, forming a mixture of air and vapor, at the end of the stroke, it ignites and drives out the piston. This engine consumes about one pint of oil per horse-power per hour.

It naturally follows that where gas engines are employed a supply of gas must always be on hand. Where gas is not to be had it becomes necessary to make it for use in a gas engine. For small powers this is not economical, but for units of from seventy-five horse-power and above, a gas-making plant is advisable. We have three forms of fuel—solid, liquid and gaseous; solid, the most common; liquid, containing the most energy; and gaseous, the most convenient. It is the tendency of the day to convert both solid and liquid fuel into gaseous. In the establishment of a power plant the question of economical power is a most important one.

The steam engine is economical and efficient only where a horse-power is developed on a pound and a half of good steam coal. This in very large units means an efficiency of about 12 per cent. In units of 200 horse power this figure may be cut in two. And in steam engines of from twenty to fifty horse-power, a horse-power is not easily developed without the expenditure of six to ten pounds of coal. Small steam engines are extremely expensive.

In contrast to the steam engine the modern gas and oil engines, from small to large units, show an economy very much above that of the steam engine. Where gas is made for use in the gas engine the cost of such an installation is about equal to the cost of steam boilers. The wear and tear on a producer is less than on boilers; with no high-pressure to carry, no loss of time waiting to get up steam, as a supply of gas is always ready in the gas holder, and,

no insurance. The Dowson gas producer is reported to be built at a less cost than the cheapest boilers; they depreciate less and occupy less space than boilers, and attention is less. The stand-by losses on boilers amounts to 10 per cent. of the fuel consumed, while in gas and oil engines no such loss can take place, for when the engines are stopped all loop-holes are absolutely closed.

Oil engines are in a measure more to be desired than gas engines in that they are available where gas cannot be easily obtained. In mountainous districts, where the value of steam coal is not only expensive in itself, but haulage is also a large item, oil would be much more easily handled and cost less.

Gas and oil engines are self-contained—are motor and furnace all in one. Boilers are not required at all. No chimney is needed, thus eliminating a great source of loss. The products of combustion are readily carried away by the exhaust pipe, so that ashes do not have to be carted away. These engines run smoothly and almost noiselessly. They do all sorts of work such as steam engines do. They are much more available and convenient than steam engines. They may be placed anywhere.

For mining purposes, hoisting and pumping, they are perfectly adapted.

Mr. C. A. Martine, of Georgetown, has two Priestman oil engines at work in the McClelland Mine. One is located 500 feet below the outcrop. This engine is belted to a triplex pump which delivers fifty gallons of water per minute against a head of 100 feet. The engine and pump are placed on a truck so both may be easily moved. This little plant has now been at work five and a half years. Repairs in this time have been very slight, but trouble was experienced in getting used to the engine. Mr. Martine further writes me:

“That under the peculiar conditions existing at the McClelland Mine, which is worked exclusively through adits driven upon the vein, no more efficient or economical prime mover than this Priestman engine has proved itself to be, could have been introduced for the work to be done, as the power is generated at the very point of consumption. About fifteen to twenty minutes are required to set it in motion.”

Mr. Martine also states that, owing to the altitude (10,000) feet, it is impossible to burn the same amount of oil at that elevation as at sea-level. At 10,000 feet the mercury stands at twenty inches, hence the power developed is but two-thirds that which could be developed at sea-level. This engine has a cylinder six inches in diameter and eight inches stroke, and runs 285 revolutions. From cards sent me by Mr. Martine, the indicated horse-power under these conditions was 2.44. Of the other oil engine used by Mr. Martine I have no data at present.

I have within the past month received some data concerning the gas power plant of the Arizona Copper Company, operating at Clifton. Through the courtesy of the general manager, Mr. Colquhoun, I learned that the company are using 360 horse-power in gas engines; one installation being employed in operating the concentrating plant and the other in running the Bessemer plant. All the engines are provided with starters, but they are not used, and they find it more convenient to take three or four laborers and start one engine, and after one engine is started all the others are started from it. It takes from five to ten minutes to start all of the engines. All of the engines used in this plant are Crossley-Otto engines, and were built in England. Dowson gas is used and the consumption is about one and one-third pounds of anthracite coal per horse-power per hour, costing \$8.00 per ton. A test for actual consumption made in the engines at the factory in England showed a consumption of seventy-five cubic feet of producer gas per horse-power per hour. The general manager also states that, in their experience, it has been best to employ the best men they can get to run these engines, and that these engines are not so suitable or as nice to work with as steam engines, but they find that they are very much more *economical*.

A test recently made on a Hornsby-Akroyd oil engine, with a cylinder seven inches in diameter, twelve-inch stroke, running at 260 revolutions and using crude oil, just as it comes out of the ground, developed 7.3 I. H.-P. and 5.1 brake H.-P. and a mechanical efficiency of 70 per cent.

During the past year over 300 gas and oil engines have been installed in the oil fields between New York and West Virginia. Both oil and gas are cheap and so operating costs very little. A Standard Oil Company superintendent states that, after careful figuring, oil can be pumped through the pipe lines with the gas engine at just one-fourteenth of the expense of the steam engine.

In response to certain inquiries, the Hercules Gas Engine Works of San Francisco give me the following account of the working of one of their gas engines. The engine in question is owned by Mr. S. H. Pierce, of California. It is a twenty-five H.-P. engine, and Mr. Pierce says it is used in driving a ten-stamp mill. With five stamps dropping, and including other machinery, the engine consumes in twenty-four hours thirty-six gallons of distillate oil. The stamps are 850 pounds each, dropping ninety-five times per minute with between five and six inches drop. The other machinery consists of a good sized rock breaker, a deep well pump, an ore elevator, and a small dynamo for lighting. The distillate oil used is of .40 gravity.

Mr. J. H. Costello has recently installed a gas engine at his mine, which is about one mile from Congress, Arizona, altitude 3,000 feet. He wrote me that it is a thirty horse-power engine, and drives one Ingersoll-Sergeant air compressor of about eighteen horse-power, two power drills, and the amount hoisted is forty-five to fifty carloads or skips in twenty hours. The oil used is distillate of .45 gravity, and is supplied from Los Angeles, costing, delivered in tank cars, fourteen cents per gallon. The oil consumption is eighteen to nineteen gallons in the twenty working hours, thus costing from \$2.50 to \$2.75 per day of twenty hours for fuel. The ore and skip weigh approximately 1,500 pounds. The average number of skips lifted in the twenty hours is forty-two, and the distance of haulage 250 feet. If we assume that the engine hoists this 1,500 pounds 100 feet per minute, the horse-power required theoretically would be 4.5. If we assume 60 per cent. efficiency, 7.5 horse-power would be actually required to do the work. The compressor and hoist are coupled together on the

same line shaft. At the altitude of 3,000 feet the engine is probably doing about all the work it can.

Until recently there have been two serious drawbacks to the introduction of gas engines—first, the high price of gas, and second, the high first cost of gas engines. In oil engines the first objection does not exist, but the second applies. Since 1890, however, when the Otto patents expired, and many companies engaged in the manufacture of gas engines, competition has greatly reduced this high first cost. The price of gas has also been greatly reduced, and special rates are readily secured for power gas. Even when a producer plant is installed the first cost is equal to or less than the cost of steam engine and boilers.

It is cheaper and results are more satisfactory to use illuminating gas in a gas engine to produce electricity than to burn it directly for light. An example will illustrate this:

“An engine using twenty cubic feet of gas of sixteen-candle power gas per horse-power per hour, is taken. This gas would furnish four five-foot burners of sixteen-candle power each, or sixty-four candle-power for one hour. Now these same twenty cubic feet used in the gas engine, developed one horse-power per hour, and this will run ten sixteen-candle power incandescent electric lights or 160-candle power for one hour. Here is a difference of ninety-six candle-power of light more than the twenty feet of gas if burned by the four five-foot burners.”

It is a mistake to suppose that gas and oil engines are only made in small units or that it is a long stride from steam to gas. Gas engines of from 100 to 250 are now common. There is little doubt that in a few years gas and oil engines of 1,000 horse-power will be as common as engines of 100 horse-power now are. A large gas engine of 400 horse-power, built by Messrs. Andrews of Reddiss, England, is driving the mill of Messrs. Spicer at Godalming. Another is the large Simplex gas engine at the Pantin (Paris) flour mills. This engine develops 300 horse-power right along, and does the work on less than one pound of coal per horse-power per hour.

There is no place where more steam goes to waste than in a



steel plant. The number of small engines scattered about is almost without number, and steam is carried to them often hundreds of feet with great loss. These might readily be replaced by gas or oil engines, and if by gas engines, a central gas plant would supply all, and with no loss at all. An instance in this connection is the utilization of the waste gases of the blast furnace in gas engines. At Wishaw, Great Britain, the waste gases from the blast furnace are collected and passed through apparatus in which the tar and other impurities are driven off and the gases thus purified are collected in a gas holder for use in the engine. This engine is of fourteen rated horse-power and is used to run the electric lighting plant. The engine, from careful experiments and calculations by the manager, develops a horse-power on one and one-half pounds of coal consumed in the blast furnace. This furnace has a capacity of 300 tons of iron a week, and the manager estimates that the waste gases would be capable of developing nearly 1,800 horse-power an hour continuously.

In most of our American blast furnaces which have a far greater capacity, *what* a field is open for the introduction of gas engines. There is always an abundance of gas after the hot blast stoves have been taken care of. All the hoists, pumps, dynamos and blowing machinery could easily be operated by gas engines using the waste gas. There can be no doubt that gas and oil engines will, on account of their high efficiency, adaptability and convenience, continue to supplant steam in many of the industries where economy must be practiced to the utmost. In England alone 100,000 horse-power of gas engines are built annually. Up to 1894 600,000 horse-power in gas engines were at work in England. In the city of London there are 2,500 of these engines, Berlin has 1,500, and 85,000 are scattered all over Germany. The number of gas and oil engines in the United States is variously estimated, but it is probably not far from 50,000, and the number is rapidly increasing.

Gas and oil engines are not without their faults, like steam engines, but at the same time, when we consider that gas and oil

engines dispense with boilers, feed pumps, chimney, ashes, skilled engineers, expensive foundations, valuable space, insurance, and that there is no bar to their installation anywhere, that they are always ready to be put into operation, night or day, at a moment's notice, with no stand-by losses as we have in steam plants, which at the lowest estimate is 10 per cent of the fuel account; that gas and oil engines are clean, reliable, safe and especially economical and efficient, it must be conceded that the value of these engines must impress power users in such a way that they cannot remain blind to, or prejudiced against, these prime movers.

#### DISCUSSION.

**Mr. Henry A. Vezin**—In Mr. Wilkinson's interesting paper he seems to lay the principal stress upon economy in fuel, a point which I consider not even second in importance. That is to say, in mines, mills, and smelting works, the considerations, in the order of their importance, are with me as follows: 1st, efficiency, certainty of action, safety, and having two strings to your bow; 2d, first cost; 3d, economy in fuel. And I think a close study of the practice amongst the best mining and smelting men will show that this order has been observed. According to the data given me by Mr. Martine, in the application of the Priestman oil engine in his mine above Georgetown, the consumption of illuminating oil per hour, the engine making 350 revolutions per minute, was 3.4 pints, the cost of which, at 15c. per gallon, is 6.4c. The net duty was 1.41 horse-power, due allowance being made for the friction in the 3" discharge pipe, and the resistance in the elbows. Adding 20 per cent. for friction in stuffing boxes and in gearing and bearings, the brake horse-power required would be 1.69 horse-power. The indicated horse-power developed by the engine at this speed was 2.7, showing a useful effect of 62.6 per cent. Of course, the resistance in the pump itself may have been more than 20 per cent., since the screwing of the stuffing boxes only slightly more than necessary increases the friction very much.

This makes the cost of the oil or fuel—

2·36c. per indicated horse-power;

4·14c. per brake horse-power;

4·5c. per effective horse-power.

If the pumping were done by steam pumps, the consumption of steam would vary from 100 pounds to 18 pounds per hour per horse-power, according to the kind of steam pump used. Assuming an evaporation of six pounds of water per pound of coal, the consumption of coal would then be 16·6 pounds to 3 pounds per hour per horse-power, costing, at \$4.00 per ton, 3·3 to 0·6c. per hour per horse-power, exclusive of that required to make up for condensation. Owing to the very small amount of water to be lifted, the simple pump, without expansion or condensation would be used, so that the cost, exclusive of condensation, would be 3·3c. per horse-power per hour, assuming, of course, *continuous* working and all parts in excellent condition; but, as Mr. Martine uses his pump only one hour in the 24, the heating up of the boiler, and the loss of all this heat in cooling down until the next time he starts up, besides the condensation, would probably make the cost for fuel 15c. to 20c. per horse-power per hour. (I may here add that the covering of the steam pipe with non-conducting material would be of no use, since it does not become effective until after steam has been passed through the pipe for two or three hours, and so, in a case of this kind, it is just as well to use the naked pipe.) The disadvantage of this arrangement would be that an extra attendant would be required at the mouth of the tunnel, for the purpose of attending to the boiler, and the total cost of the plant would be much greater. He would, therefore, probably find the cost of fuel less with the present arrangement, even though the fuel per useful horse-power cost him at least 20c. per hour, apart from the great convenience of being able to shift his pumping plant to any part of the mine. It is the great convenience of having the entire plant concentrated in virtually the one machine, without the need of a plant on the surface to supply either steam or electricity, and convey the same to where the power is to be applied, that con-

stitutes the great and important advantage of this engine over those heretofore used, and I think that Mr. Wilkinson neglects to bring out fully enough this important advantage of these engines, at least for small powers.

An illustration of the difference which could have been obtained by using a Priestman engine in the place of a steam plant was very well shown in what was done at a mine some ten or twelve miles above Georgetown, and above timber-line. An underground hoist and an underground pump were required at a distance of about 600 feet from the mouth of the tunnel. Two boilers were set up near the mouth of the tunnel, and the steam was conveyed to the machinery, a little scrub hoisting engine and an ordinary steam pump, stationed inside. A  $1\frac{1}{2}$ " steam pipe would have been ample for the maximum amount of steam required, but the men who had the pipe to sell advised using  $2\frac{1}{2}$ " pipe, so as to be sure to "have the steam get there." Their disinterested advice was followed, there being a strange notion amongst mining men that steam has difficulty in flowing through a pipe. Coal would cost probably \$10 a ton, and the cord-wood which was really used, and which had to be hauled up-hill, in the same proportion, so that the cost of fuel per horse-power per hour would undoubtedly be at least 15c. to 20c. and a good deal more, in case the machinery was not running constantly, since the condensation in this large pipe would be going on, no matter whether steam was consumed by the engine or not. It is much more probable that the cost would be 25c. at least. The whole plant was much more expensive, and the exhaust steam would be of little or no use in ventilating the mine. Steam could, of course, be used in a separate little engine with a blower for ventilation. The much cheaper plant, requiring no fireman at the boiler house, and no steam pipe, would incidentally give another advantage—that is, the exhaust from the oil engine could be used to ventilate all the workings of the mine by *artificial* ventilation, by using the raises which lead to the surface; and that is the only kind of ventilation which can be always depended on. The pump may be driven either by means of wire rope transmis-

sion or rod, in case it would be necessary to lower it frequently. The very long test made by Mr. Martine was sufficient to inspire confidence in the application of a machine of this kind. I think that the engine, for small powers, far from boiler plants or electric generators, certainly must be considered as having gained a position it deserves; and it was only because Mr. Martine had studied the engine as well as he could before sending for one, and that he is very patient and very persistent, that it has not met the fate of so many other machines. According to the old practice, the machine would have been thrown over the dump in a very few days. It ran very well in starting, but, before making many revolutions, it stopped. Different sizes of pulleys were tried, all sorts of changes in the method of transmission, but still it would not run continuously, until the idea struck him that the light atmosphere had something to do with it. He changed the governor valve which regulates the amount of atomized oil, and the difficulty was solved. The whole trouble lay in the fact that the amount of air taken into the cylinder was not sufficient to oxidize all the oil, so carbon was reduced, and, collecting on the points of the electrodes, made a connection which prevented a spark, and the result was that there was no explosion. Since that experience the manufacturers test the engines at the atmospheric pressure at which they are to work.

Mr. Martine tells me that two gasoline engines in the city of Denver exploded, one of which killed the attendant engineer. He does not say whether the cause was necessarily due to the system, or to negligence on the part of the attendant. To me gasoline always seems an exceedingly dangerous material to have around, much worse than gun powder, since it volatilizes at a very low temperature, and, unless the gas is carried away very rapidly, may form an explosive mixture with the air surrounding the can, or other vessel which holds it. I should certainly consider it unsafe to use in a mine where candles or lamps have to be used, unless the ventilation is very much better than in most Colorado mines. The fact that insurance companies charge no higher rate when such

an engine is used, seems, of course, to justify the use of these instead of oil. The advantage lies merely in the lower cost of the engine itself, and that is not a serious consideration. The ventilation necessary, which should be by means of a fan blower, driven from the main engine or a separate small one, driving the foul air and gasoline and the exhaust from the engine through a pipe, without contaminating the rest of the air in the mine, could, as a matter of course, be very easily applied. I should like to ask Mr. Wilkinson how large engines have been used successfully?

Mr. Wilkinson: One of 400 horse-power, driving a mill and consisting of a double engine.

Mr. Vezin: Then we can count on using a single cylinder mill engine of 200 horse-power?

Mr. Wilkinson: Yes.

Mr. Vezin: I cannot agree with Mr. Wilkinson in what he says as to it not requiring a skilled attendant to run an oil or gas engine. Whenever machinery is used that needs adjusting, proper skill is required. The same argument was used about the year 1868, by gentlemen who were interested in the manufacture of a small steam engine, the Hicks, having four single acting cylinders and no slide valves, and their enthusiasm about the engine seemed to be confirmed by the users, who required but small power. One of the greatest advantages claimed for the engine was that, "apart from its simplicity, any boy could run it." Of course, any boy could turn the steam on and off, but that could hardly be considered running the engine. Quite a number were sold; the users seemed delighted. All at once they commenced throwing them out on the scrap heap; it seemed as if they hardly could do it quickly enough, and this in spite of this great advantage claimed for it. The enthusiastic advocates of this engine attributed my disapproval of it to my "being wedded to my old ideas."

Mr. Louis C. Hill.—The thanks of the Society are, I think, due to Mr. Wilkinson for bringing to the attention of this body a

prime mover of great interest to all of us who have need for power.

Considerable difficulties have been encountered by users of gas engines of large powers. Comparatively few of the larger sizes are in use, while many thousands of the smaller sizes of engines of this type are furnishing power in many countries.

For small powers, especially when used intermittently, a gas, oil or gasoline engine is fairly economical and its great convenience makes it a very desirable machine.

For hoisting purposes it is not well adapted, owing to difficulties in starting. If run continuously for this purpose and the hoist is worked by clutch or belt and clutch pulley, it is very uneconomical, as these engines are very inefficient when running on light loads.

For very large plants, running continuously, a steam engine will usually be found to be more reliable, and cheaper to operate, except under conditions where coal, suitable for making producer gas of good quality, may be obtained at a very low rate.

In certain locations where fuel must be hauled by wagon long distances and where water suitable for boilers is difficult to obtain, oil or gasoline engines might easily prove to be more economical in operation than steam engines.

For operating hoists and pumps underground, at great distances from the surface, compressed air or electricity would certainly be preferable, at least where a considerable amount of power was required. For small amounts of power, used intermittently—unless the mine were already lighted by electricity, or piped with air for drills—the oil or gasoline engine would be both cheaper in the first cost and cheaper to operate.

Convenience in operation may easily in many cases decide the motive power to be used; the total cost of operation being so small an item as to be entirely overshadowed by other considerations. An example of this is shown in Mr. Vezin's discussion of Mr. Wilkinson's paper. From data furnished by Mr. Martine, he finds the cost for fuel per horse-power hour to be  $4\frac{1}{2}c.$ , figured on the

basis of the theoretical horse-power required to lift the water through the pipe. As it is necessary to run this engine, I believe, but about one hour each day to free the mine from water, and the necessary power is but 1.41 horse-power, the total cost of fuel per day is but 6.4c., or about \$23 or \$24 per year. If fuel cost ten times as much, the total expenditure per year would be so small in this case as to influence but little the choice of motive power.

**Mr. Thomas L. Wilkinson.**—I wish to make a correction of an error in my paper. I stated that the quantity of oil used in the Priestman oil engine was about one and one-half pints per horse-power per hour. I should have said one and one-fifth pints.

The question of large sized engines was brought up, and since then I am able to give additional data. At the Hoerde (Westphalia) Iron Works, a 900 horse-power gas motor, using furnace gas, has been in operation since last September. The mechanical efficiency of this engine, on testing, was found to be .766.

The Westinghouse Machine Company have in their shops, a 750 horse-power gas engine, which is convertible into 1,000 horse-power. It is also reported that this company is preparing to build still larger sizes.

A new motor, the Deisel, is at present being brought out, in which the combustion is at a *constant temperature*. In this engine pressures are used which, heretofore, have never been attempted, namely, thirty-five atmospheres. This engine has developed a mechanical efficiency of 75 per cent. Both the gas and air are previously compressed before being brought together in the engine.

It is certainly gratifying that Mr. Vezin endorses my paper, and, in addition, gives some data concerning Mr. Martine's plant, that I did not have.

Of his discussion I have little to say, in answer, except on two or three points.

In the first place, Mr. Vezin takes exception to my position as the importance of economy.



While I made my remarks general, he seems to confine himself to the economy as practiced in mining and smelting plants only. It has been my observation, that in this latter class of plants, Mr. Vezin's order of importance is somewhat distorted. Under existing conditions, in this class of plants, I am at a loss what to place as of first importance—surely not *efficiency*, which I should place, in his order, just before *economy in coal*, which he places last. I think that mining and smelting plants burn far too much coal for the results obtained.

Competition, especially where it is very close, has made *economy* of operation a necessity. This has not been the case in the West, until now. Wherever the fuel account can be kept down, other things being equal, *economy* of operation will surely result. The leading engineers of this country, who are experts in steam engineering, take the same view, and they all say that the principal items of cost (of operation) are fuel and attendance.

I made reference to the Milwaukee pumping plant in my paper, and I quote a few items of expense in support of my assertion.

The cost of the plant, as given by the city engineer of Milwaukee, is as follows:

Cost of engines (and pumps) and four boilers, including foundations and boiler settings.....	\$ 81,000
Cost of so much of the building and boiler house as is chargeable to the engine.....	31,500
Total cost.....	\$112,500

The cost of operating in 1892 (6,980 hours) with coal at \$5.95 per 2,000 pounds, was \$28,107.10.

Reduced to 365 days of 24 hours, and cost of coal at \$5.00 per ton (2,240 pounds), the cost will be:

Coal .....	\$17,275
Engineers' wages .....	10,680
Repairs to engine and boilers .....	414
Oil and waste .....	466
Packing .....	288
	<hr/>
	\$29,105
Interest on plant, at 5 per cent. ....	5,612
Depreciation, at 4 per cent. ....	4,500
	<hr/>
Total cost of 365 days (24 hours) operation and main- tenance .....	\$39,217

The consumption of coal was 1.57 pounds per horse-power per hour, and the steam consumption was 11.67 pounds per horse-power per hour.

As this is one of the most economical plants ever built, it may be pointed to as one in which the best practice of steam engineering has been observed.

It is almost unnecessary to call attention to the fact that the principal item of cost of operation is the fuel account. Suppose we add 10 per cent. of the fuel account, which might easily result on account of poor firing, and the wages of the firemen become exceedingly small in comparison to the loss he incurs. It is the coal pile that must be watched, and it is really of great importance that the boiler end of a plant should be judiciously handled.

It is said that gas and oil engines owe their popularity not to efficiency, but to their convenience and adaptability. That may have been the case some years ago, and may be yet, in some cases, but when we see steam replaced by oil and gas, the claim will hardly hold.

There is a mine in the La Plata Mountains, this State, where the cost of operation of a steam plant is prohibitive and the owners are now considering the use of an oil engine solely on the ground of *economy* of operation.

In the matter of skilled attendance in the running of gas and oil engine, especially those of small power, I am inclined to hold the position I have taken, in that *skilled engineers* are unnecessary. When we speak of skilled attendance in connection with this class of engines in comparison to the duties which fall to the lot of the steam engine driver, it will be found that they differ materially.

The duties of the runner of a steam engine do not stop with the opening and closing of the steam valve and oiling; he has many other things to attend to about his plant which keep him in constant attendance, while in the gas and oil engine work, after starting and oiling, there is practically nothing to do, and a skilled man would not only be expensive but would have time hanging heavily on his hands. The starting and stopping of a gas or oil engine, after a few trials, becomes mechanical and the operator is generally employed at some other work.

Mr. Colquhoun says they employ the best men they can get to run their engines at Clifton, but even this statement is rather indefinite and conveys no idea as to the qualifications of the men so employed.

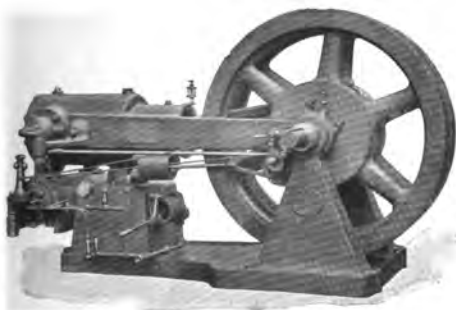
The owner of a gas or oil engine naturally selects a man to care for his engine, who has at least a few grains of intelligence, but need not be skilled in the least.

I hardly think Mr. Martine employs a skilled man to operate his oil engine pumping plant, which he works but once or twice in a week. Nor does Mr. Henry Wood, who employs a gas engine in his laboratory.

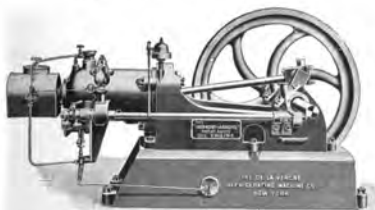
I have no records of any special difficulty encountered by the users of large gas or oil engines, nor have I heard of any such as Mr. Hill mentions. There should be no more trouble in operating a large gas engine than a large steam engine, and I think not nearly so much. The large Simplex gas engine which runs the flour mill near Paris, a recent report says, is easily and readily started and the work it does is perfectly satisfactory. This engine develops between 250 and 300 horse-power.

The application of gas and oil engines to mining is comparatively recent, yet from data I have, I find no such obstacles in the way of successful hoisting as Mr. Hill suggests. Mr. Costello is very well satisfied with the work his engine does and hoisting is a large part of it.

I think Mr. Hill should have been more positive when he said that "in certain locations where fuel must be hauled, etc., oil or gasoline engines *might* easily prove to be more economical in operation than steam engines." The fact is that they are, and even in very small powers these engines are just as economical, if not more so, than the best triple expansion steam engines.



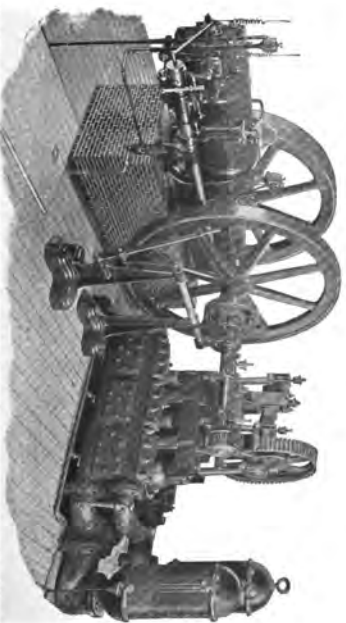
Ten Horse-Power Priestman Safety Oil Engine.



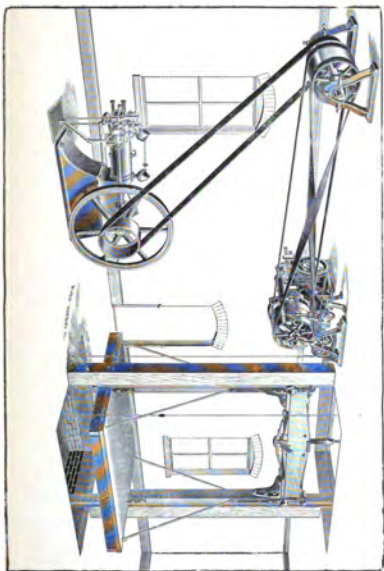
Hornsby-Karney Oil Engine.

Eight and One Half Horse Power (actual) "Otto" Special Electric Light Engine, directly belted to dynamo.





One of the two engines and pumps installed at the Dundee Water Works, Dundee, Ill. The engines are Otto engines, of thirty six actual horse power each, direct connected to Deming triplex pumps, with a capacity of 500,000 gallons per twenty-four hours. (Machine is used in these engines.



Elevator Operated by Otto Gas Engine.



## A MINERALOGICAL MISTAKE.

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BY P. H. VAN DIEST.

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Meeting of May 7, 1898.

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When we occasionally have the curiosity to know something about the early history of great mines and big producers, we notice that the discovery of these sources of wealth is but seldom due to a close study of the relations of rocks to minerals, of the effects of long exposure to atmosphere and moisture, of the detritus carried by water courses, of changes in the configuration of the surface, in the color of rocks, and even in the vegetations; in short, it is not due to investigations in the field by scientific men. Nearly always it is the prospector who, with but few notions about minerals, relying on his scent or instinct, perseverance and "good luck," by intuition, so to speak, stumbles upon outcrops of mineral-bearing veins or deposits, which become, in course of time, producers of wealth.

We hear occasionally of a successful prospector, successful in finding a valuable ore-deposit, although seldom successful in holding on to it, and developing it for his own benefit, thereby reaping a reward for privations and perseverance. But hardly ever do we hear of the many enthusiasts who give up all comforts, leave their families, exhaust their savings, and roam alone over hills and mountains, with a blanket for nightly shelter, with scanty provisions and a few implements for digging and cooking; men who are never discouraged, who have an abounding faith in "luck," completely wrapped up in their pursuit; elated over the least change in the appearance of quartz or about bright or dark specks

in the rock, different from those they had seen before; hoping that every piece of float or blossom that they may pick up may be the bud which, in blossoming, will become a rich property that will make them comfortable to the end of their days, hopes that are fulfilled only in their wild dreams of discoveries of minerals and wealth.

The life of such prospectors is not interesting, however useful and necessary they are as a body that counts as members a few who discover rich veins and ore deposits; but we feel sad when we feel how some of them, for a whole lifetime, will stick to a fixed idea or a false notion, and, with unshakable faith, cling to what they think must lead to a fortune.

Old Judge X, one of the pioneers who settled in southern Colorado long before Denver was more than a hamlet, had an inspiration, several years ago, that in Colorado there must exist in great quantities tin ore as well as other minerals, and he became convinced that he had found it on the slope of Greenhorn Mountain.

Never having seen tin ore, only knowing that it is heavy, often brownish-red in color, and never thinking that other minerals strikingly resemble it, he took up several claims, and started to open them by cuts and shafts. So earnest was Judge X in his prospecting, and in the investing of all his means, that the desire for further discoveries became contagious, and others took up claims near his, thus spreading abroad the rumor of the existence of a tin mine in Colorado, to such an extent that in one of the bulletins of the U. S. Geological Survey, Greenhorn Mountain is mentioned in the list of places where tin ore occurs in the United States.

I had often heard of this tin mine, and felt quite pleased with a request, last summer, to examine the property, and to give advice as to its further development. This request came from a firm of lawyers whom Judge X had interested in the property. One of that firm, who came over to visit the mine with me, told me that in 1896 they had, on the ground, an assayer and chemist, residing

then in Omaha, who had reported that the ore contained 3 per cent. of tin oxide, and had given them a piece of tin which was shown me as smelted out of the ore. This firm had since invested fully \$8,000 in shaft sinking, drifting, etc., and was willing to invest many more thousands, but desired advice that they might spend them in such a way as to make the mine very soon a "great producer of tin," the "pride of Colorado," etc.

I found the mine located at the southeast slope of Greenhorn Mountain, near the head of a gulch coursing to the Huerfano River. The location is about seven miles N. N. W. of St. Mary's P. O., and thirteen miles from Walsenburg.

From the Huerfano, going northerly, one travels for several miles over a flat country, sparingly covered with grasses. The white and yellow, friable, sandy, low ledges sticking out of a loamy soil, show the formation there to belong to the Colorado group of the Cretaceous. Thence passing through a low, narrow canon, scored out of the sandstones of the Dakota and the red clays and red sandstones of the Trias, the gulch soon widens, the water-course forks leaving between the two branches a hillock or spur of the mountain, which, by erosion, is denuded from the once overlying Mesozoic beds which, on both sides, form, in nearly horizontal layers, the slopes of the mountain. All Paleozoic beds which may have been deposited on the schistose rock forming the denuded hill or spur, have been washed away. Or, more likely, this portion of the mountain was not submerged during that period. The exposed schists in the mountain gap form the apex, and follow the axis of an anti-clinal sharp fold in this metaphoric rock. Higher up the schists disappear under remnants of red beds to appear again still higher on the Greenhorn Mountain which, at its summit, is undoubtedly archæan.

The trench or cut made near X's shaft shows the schists standing about vertical, and with a strike nearly north and south. On the east side of the trench the schists have a granitic appearance of coarse grain, alternating with sheets of a light-greenish, much decomposed, chloritic shale, two to three feet in thickness. Then

follows a succession of micaceous and hornblendic schists, some schistose and fine-grained, others more massive and coarse. The micaceous sheets have seldom a thickness of more than six inches, but the more massive hornblende sheets attain twelve and more feet in thickness. These amphibolitic schists are traversed by granitic and pegmatitic veins which can best be seen more to the west in the bottom and sides of the gulch. The coarse hornblende rocks contain garnets of a dull ruby color. These garnets are in small grains dispersed through the rock, but sometimes accumulated in spots to the size of a pea or bean, with a suggestion of an original dodecahedral form, much cracked and fractured, probably by compression during the folding of the schistose mass.

I had no time during my visit to find the connection of these schistose series with the archæan, but I got the impression that they are of the same character, and of the same pre-Cambrian age as those occurring near Salida, and described by Whitman Cross in volume IV, pages 286-294, Proceedings of the Colorado Scientific Society.

In the garnetiferous hornblende rock a shaft is sunk to a depth of 140 feet, with drifts at 80 and 120 feet down. These drifts run in all directions in search for walls which were not found, or in following some quartzey veinlets which disappeared or widened to a lenticular enclosure of a more granitic appearance. The garnets and other specifically heavy ingredients of this hornblende rock, the judge and his associates considered to be the precious tin ore of their mine.

From average samples on the dump, and from drifts, I took several pulverized portions, each 300 grams in weight, and, by washing, saved 7-8 grams, or  $2\frac{1}{2}$  per cent. of a heavy material having a specific weight of 3.95, or a little over the average specific gravity of garnet. The gravity of tin ore being 6.8, very little of that ore could have been mixed with the mass.

By close inspection of the heavy residue, and separation with pincers of similar grains from the rest, I found about 10 per cent. of black particles, being a titaniferous iron, specific gravity 4.5,

slightly magnetic; further 80 or 85 per cent. of small garnets, and the balance particles of a light wine-red or white color, being zircon and sphene. The garnets were easily distinguished from the colored zircon by being somewhat fusible, the zircon not, and by becoming colorless in the flame.

To be sure that no tin ore occurred with the garnets in the rock, even in minute quantities, I smelted five grams of the heavy material which was washed out of the rock, and finely pulverized in an agate mortar, with potassium cyanide, and another portion of five grams with charcoal, fluorspar, soda, and a borax cover, without obtaining the smallest pellet of tin. The slags in the crucibles showed the beautiful green color of chromium, always slightly present in garnets. I also fused some of the material with caustic potash, and boiled it with dilute hydrochloric acid, but did not get a precipitate with zinc. I assayed the garnetiferous residue of the panned hornblende rock, and found that it contained 0.18 ounces of gold, or \$3.60 per ton, which gives the hornblende rock in the ratio of 40 to 1 of concentration, a value of about nine cents in gold per ton. The quartz material of small veins in the rock assayed 0.08 ounces or \$1.60 per ton in gold. By these tests I demonstrated to the interested Omaha lawyers that they had invested in a worthless property, but I did not succeed in convincing the old judge that there is no tin ore in his mine. I believe that he is still hoping for ultimate success, and is trying to place a fraction of the stock of his company for further developments and mining for tin.

#### DISCUSSION.

**Mr. R. C. Hills.**—I believe I am, to some extent, responsible for the Huerfano tin "excitement." Several years ago, in conversation with a ranchman of that section, I mentioned the fact that very few persons had prospected for tin ore in Colorado, and suggested that such ore might possibly be found in the Sangre de Cristo or Greenhorn ranges. Shortly after, that same ranchman and several of his neighbors began searching for tin ore, and

samples were sent me from time to time, which proved to be nothing but garnet. Later on, globules of metallic tin were received as proof that the ore had really been found, but the rock from which the prills were said to have been obtained, refused to yield even a trace of tin when properly tested. An acquaintance living at Walsenburg melted some of the rock in a crucible, and obtained a number of prills which he sent me for examination. They proved to be simply globules of metallic iron. In the fall of '96 I personally visited the locality described by Mr. van Diest, and carefully examined the material upon which excavations had been made. I found bands of silicious rock containing an abundance of brown garnet and green epidote, but in no case could I detect anything having the remotest resemblance to tin ore, unless it might be the garnet, which in color really resembles some varieties of tin stone. In my report to the director for that year, I took occasion to mention my visit and state my conclusion, which I trust may operate to correct any misapprehension that the statement said to have appeared in a government report, may have given rise to.

**Prof. Chas. S. Palmer.**—I am much interested in this notice of "the reported tin mine of southern Colorado." It is a good instance of the credulity of some men in insisting on finding what they want to find, and an equally good illustration of incredulity in rejecting the testimony of chemical analysis. Two or three years ago, the pioneer referred to in Prof. van Diest's paper sent me a box of the "ore," stating that the Denver assayers had universally failed to find tin, but that he (Judge X) had invariably found it. He also kindly ventured some criticisms on the methods usually employed, and outlined one used by himself. Of course I did not believe that a good tin ore could slip through the hands of our standard Denver workers without showing its nature, but at the urgent solicitation of a son of Judge X (who was then a student in the chemical department of the University, and who was taking chemistry with the sole object of ascertaining something about tin) we gave it a thorough trial with completely

negative results. The young man then left chemistry to study law. All of us are, of course, frequently called upon to test "reported tin ore." I have invariably found none. The last "fake" was a garnetiferous rock from near Morrison. Titaniferous iron is also a common agent in victimizing the over-sanguine prospector. In connection with the Morrison find, a wicked act of forging a completely false analysis was an interesting feature. The name of the forger is withheld as he is a graduate of one of the institutions of this State, but perhaps he should be publicly reprimanded, and branded as a scoundrel. We are willing to find tin when it is in the ore, but we can only report what we find.





NOTES ON THE OCCURRENCE OF SELENIUM WITH  
PYRITE RICH IN GOLD AND SILVER,

AND

REMARKS ON A GOLD NUGGET FROM MONTANA.

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BY RICHARD PEARCE.

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Meeting of June 6, 1886.

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Some few months ago Mr. C. A. Martine drew my attention to a very peculiar ore which he found in Mexico. An assay of a pulp sample which he sent to me gave:

	<i>Oz. per ton.</i>	
Au.....	14.28	14.3
Ag.....	124.00	122.5

Some pieces of the ore were also handed to me for examination. It was simply a mixture of what appeared to be pure pyrite with quartz.

Although there were no evidences of the existence of any tellurium mineral, or, in fact, of any other mineral to account for the presence of such a large amount of gold and silver, I was led to make some investigations, and found that selenium was present in well-marked quantities. It is probable that a portion, if not the whole, of the gold exists as an alloy of Au and Ag, but in what form the silver occurs it is difficult to determine. A careful examination with the aid of the microscope failed to discover any evidence of Naumannite,  $\text{Ag}_2\text{Se}$ , or, in fact, any other mineral, to account for the Ag and Se.

It is probable that further investigation on some fresh material may throw some light on this interesting occurrence.

A nugget of gold was exhibited at the meeting by Mr. Pearce which illustrates the genesis of nuggets. The specimen was found in a hole in the bed-rock at Bear Gulch, Montana.

It consists of a rounded nodule of quartz and limonite, showing a distinct vein of quartz rich in gold. A large portion of the gold is rounded and polished by attrition, and shows a distinct nugget condition, and there appears to be evidences of the growth of the nugget surfaces by what might be termed natural welding.

The limonite which forms a large portion of the specimen, was found to contain tellurium to the extent of 1.63 per cent.

An analysis of that portion of the limonite which was soluble in hydrochloric acid, gave:

Te .....	1.63
Fe .....	42.94
Al <sub>2</sub> O <sub>3</sub> .....	20.05
With traces of Ag, Bi and Zn.	

The insoluble portion gave:

SiO <sub>2</sub> .....	19.90
Te .....	0.19
CaO .....	0.32
Fe <sub>2</sub> O <sub>3</sub> , Al <sub>2</sub> O <sub>3</sub> .....	0.87

The existence of Te in the limonite would indicate that a portion of the gold, in all probability, was combined with that element as a "telluride" associated with pyrite, and, as a result of surface oxidation, the Te was oxidized and combined with the Fe<sub>2</sub>O<sub>3</sub>, the gold being set free as brown sponge gold.

Veins of quartz with pyrite containing gold and Te are found and mined at this time in the mountains contiguous to Bear Gulch. So, in all probability, this specimen came originally from near the surface of one of these veins.

It requires no very great stretch of the imagination to believe that possibly the nuggets may owe a portion of their growth to the sponge or brown gold, which is always liberated by the oxidation of tellurides, by some process of welding. The idea is novel,

but it perhaps deserves just as much consideration as some of the theories which have been advanced from time to time relative to the genesis of nuggets. The weight of the auriferous nodule is 1054.2 grams; specific gravity, 5.25. If we estimate the specific gravity of the quartz and limonite gangue at 3.20, and assume the specific gravity of the gold to be 19.35 (which is perhaps a trifle too high) the nodule contains 493.2 grams of gold, or 15.8 ounces Troy, or 46.784 per cent. gold.

Mr. Pearce presented to the Society a specimen of Huebnerite, from the Gagnon Mine, Butte, Montana. The specimen came from the stope over the 1,000-foot level, and was associated with zinc blende, bornite and pyrite.

The occurrence of Huebnerite in copper veins is somewhat rare. It was found some years ago at the Combination Mine, near Phillipsburg, Montana, associated with a rare mineral, pseudomalachite, and recently it has been found in small quantities in the sulphide ores of the Ward District, Boulder County, Colorado, with copper and iron pyrites.

## NOTE ON THE RESISTANCE OF MATERIALS SUB- JECTED TO COMPRESSIVE STRESS.

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By C. W. COMSTOCK.

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Meeting of October 1, 1898.

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From the beginning of the study of the resistance of materials it has been assumed as an axiom that rupture is determined by a certain stress per unit area, the numerical value of this stress depending on the character of the material. So long as experiments were confined to simple tension, or, what was more usual, transverse tests on beams which in most cases failed on the tension side, no discrepancies of any account were noticed. When experiments in compression were undertaken it soon became apparent that no such regularity and certainty in the behavior of the pieces tested as had been observed by materials tested in other ways, could be expected. Anomalies too great to be ascribed to errors of observation or to imperfect homogeneity of material, were continually being noted. And yet the axiom (?) above referred to was and still is very generally regarded as so obvious that there is no room for argument.

As early as 1682 Mariotte said "Material ruptures only when the extension surpasses a certain proportion," and in 1839 Poncelet, following the same idea, wrote: "The approximation of the molecules can never be a cause of disaggregation, and it is very evident that if a prism should be compressed in all directions with an equal force it would never rupture." In this view they had a few followers, and among them many of the ablest and best informed physicists of their times, but for the most part engineers and physicists the world over clung tenaciously to the earlier idea.

Experiments on the compressive strength of materials have been multiplied to such an extent that one can hardly hope to be conversant with half of them, and yet every attempt to evolve from them a law on which might be based predictions as to the behavior of other pieces of the same or similar material has signally failed. Our knowledge of the resistance of materials to a compressive stress is therefore purely empirical. Every engineer knows that any statement of the compressive strength of a certain material is valueless unless accompanied by a description of the form and dimensions of the test piece and of the means of applying the load. We are all familiar with the ordinary statement regarding brick, that the compressive stresses per unit area necessary to determine the rupture of a quarter, half, three-quarters and whole brick are in the ratio of 3, 4, 5, 6. These facts and many others of a similar nature are not only not explainable on the hypothesis mentioned at the beginning of this paper but are in direct contradiction to it. Poncelet's theory of rupture offers acceptable explanations of these apparent anomalies. It is well known that the longitudinal contraction resulting from a compressive stress is accompanied by a transverse dilatation which varies in amount in different materials, but is generally from one-fourth to one-third the corresponding contraction. This dilatation would be uniform throughout the length of the test piece if the applied forces were reducible to a single resultant along the axis of the piece. However, the frictional forces developed between the face of the specimen and the face of the crushing tool prevent either partially or entirely the lateral extension at that place. The result is that the piece bulges, assuming—if it were originally cylindrical—a barrel shape. The greatest extension takes place at the middle of the length, but the absolute value of this extension depends on the ratio of length to lateral dimensions and probably also on the form of the cross-section, as well as on the force to which it is subject. The law of this dependence is at present unknown but I think it need not remain so.

In order to test Poncelet's statement (quoted above) I placed

in the reservoir under the plunger of a large hydraulic jack some buckshot, several nearly spherical beads of annealed glass and some small cubes of a compact fine-grained sandstone. The pressure of the fluid in the reservoir was then raised to ten thousand pounds per square inch. The pieces were entirely unaltered so far as could be determined from a superficial examination. None of these materials withstood more than a small fraction of this stress when it was applied on two opposite faces only, as is done in the ordinary compression test. This, as far as it goes, is evidence of the truth of the statement in question.

According to Laplace's law of the variation of the earth's density the pressure at the center of the earth is twenty-two thousand tons per square inch. We have no knowledge of any material which would withstand such a pressure unless applied in such a way as to prevent all dilatation.

Some years since I had occasion to test some cement mortars. The test pieces were each four inches square and their heights varied from a quarter of an inch to four inches. The cubes failed at about one thousand pounds per square inch. The thinner pieces required more and the one-quarter inch slab received a load of four hundred and two thousand pounds. As this was one ton more than a nominal capacity of the testing machine it was thought best to stop. When taken out, the specimen, beyond a slight crumbling of the edges, was perfectly sound. The frictional forces above mentioned, aided by the adhesion of the plaster of paris used in bedding, had been sufficient to prevent any appreciable extension and in the absence of this a compressive stress of more than twenty-five thousand pounds per square inch had not injured the piece.

Recently I tested a number of brick piers. They were thirteen inches square and varied in height from two and a half to seven and a half feet. The load necessary to produce rupture was greater as the height was less, though the relation between load and height was not evident. The interesting point, however, in connection with the present question is the method of failure. In

every case this began with the development of longitudinal cracks about the middle of the height. The inference is evident.

Prof. Merriam has made what seems to me an erroneous deduction from the observed fact of lateral extension. He says, in effect, that since this extension exists, it follows that there also exists a corresponding tension on all planes parallel to the lateral faces. This is equivalent to saying that a stress can produce only a strain of its own kind, a statement which is hardly warranted by our present knowledge.

All the evidence which I have been able to collect tends to show that it is *extension* and *not stress* which determines rupture, and since all other methods of analysis of compression tests have produced no results, it would seem that this theory is worthy some attention.

Mr. F. S. Watkins, in discussing this paper, spoke of the knife edges used in testing machines and scales. He said these knife edges invariably carried much larger loads than theory indicated to be possible, and thought the subject required further study.

Mr. Richard Pearce presented to the Society a specimen of mineral broken from the surface rock near the summit of the highest peak of the Sierra Blanca, and sent him by Mr. P. H. van Diest. Mr. Pearce quoted from Mr. van Diest's letter, as follows:

"It looks to me to be a telluride ore and as I have no means here for analyzing it, I take the liberty to forward it to you. It is possibly a variety of Nagyagite or of a Petzite, but it may be a not yet observed form of a silver-gold telluride. I find the ratio of gold to silver to be one to ten. In spots I observed free gold in a rusty form—probably the result of decomposition of the telluride mineral.

"The occurrence is described as follows: The lode is situated on the northwest slope of the main peak (Sierra Blanca) four hundred feet vertically and three hundred feet horizontally from the highest point on the mountain. The quartz vein in which this ore occurs, apparently in spots or bunches, varies in width from one to two feet, and stands out and is plainly visible across the entire width of Bear Creek basin. Similar bunches of ore are found in a parallel vein only eighty feet distant and similar to this one in every respect except that it is slightly narrower. Its surface exposure is almost equally well defined. The entire width of the basin, from peak to peak, does not exceed 2,700 feet horizontal measurement. Four veins are to be

seen in the basin, all of them well defined. The other two veins carry large quantities of iron pyrites. The sample sent is from the first lode, named the Beckwith. For five hundred feet in height, up to the main mountain summit, the vein presents a curious extended S shape, alternately dipping out of and into the mountain from the upper to the lower lobe of the S. The vein is free from the country rock and without any talcose parting. The quartz is milk white and coarsely crystalline. The country rock on the peak and in the basin is eruptive andesite.

"If you find this mineral to be in any way remarkable and a telluride, would you place one of the pieces in the collection of our Society?"

Continuing, Mr. Pearce said:

Carefully selected portions of this mineral were analyzed by Mr. F. C. Knight, a member of this Society, with the following results:

Ag .....	40.25
Au .....	4.30
Pb .....	2.25
Bi .....	16.31
Te .....	34.60
S .....	0.54
Insoluble residue .....	0.54
	<hr/>
	98.79

Disregarding the S and insoluble residue, the composition of this mineral is:

Ag .....	41.18
Au .....	4.41
Pb .....	2.30
Bi .....	16.68
Te .....	35.41
	<hr/>
	99.98

It was found that the mineral varied somewhat in character, which may indicate the existence of some other mineral, possibly Hessite. A small fragment of what was supposed to be of a different character from the main bulk of mineral gave 60 per cent. Ag and 1.06 per cent. Au, which corresponds closely to the mineral Hessite.

An analysis was made of a further portion of the mineral



separated, as far as possible, from the supposed Hessite, with the following results:

Ag.....	34.62
Au.....	1.75
Pb.....	2.50
Bi.....	18.08
Te.....	40.44
Insoluble residue.....	2.25
	<hr/>
	99.62

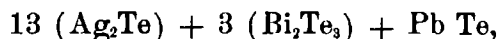
Deducting the insoluble residue, the analysis of the pure mineral would be:

Ag.....	35.55	} Equivalent in Ag. 38.81
Au.....	1.79	
Pb.....	2.56	
Bi.....	18.54	
Te.....	41.53	
	<hr/>	
	99.97	

or a ratio of

$$\text{Ag} : \text{Bi} : \text{Te} : \text{Pb} :: 26 : 6 : 23 : 1,$$

representing a possible formula of



assuming the Au represents an equivalent of Ag. The percentage required by this formula is:

Ag.....	38.88
Pb.....	2.88
Bi.....	17.45
Te.....	40.77
	<hr/>
	99.98

I have gone carefully through the list of all the hitherto discovered tellurides, and can find nothing that corresponds in composition and general physical character with this new discovery, and my impression is that it will be found to be a new species.

The mineral was broken from the vein exposed at the surface,

and, as Prof. van Diest suggests, may possibly show better defined characteristics in depth.

**Mr. P. H. van Diest**, in answer to some questions, further described the occurrence of this mineral and illustrated it by black-board sketches.

**Mr. Pearce** presented to the Society two specimens of sylvanite, one from Clear Creek and one from Gilpin County, and a specimen of Turquoise from the Last Chance Mine at Creede.

**Mr. W. L. Austin** mentioned an instance which had recently come under his observation, of a dike of diorite which carried about \$4.00 in gold. The dike comes up through the Cretaceous shales, and there are no known mineral veins in the neighborhood.

## MATTING BLAST FURNACE PLANT OPERATED AT BUENA VISTA, COLORADO.

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BY L. S. AUSTIN.

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Meeting of November 5, 1898.

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The plant consisted of a blast furnace building containing one large blast furnace (42" x 120") with open top, down take, and stack; of a building containing a hot blast stove of the Nesmyth patent, the air being heated by residuum oil from Florence, Colorado; of a blower building containing a No. 6 and a No. 3½ Connersville blower. These blowers were operated by an electric motor, which received its current from a generator at the water power building, situated on the Arkansas River near by. A series of ore bins, 300 feet from the furnace building, carried a supply of ore and fluxes.

The hot-blast stove heated the air to as high as 800° Fahr. by oil jets whose products and combustion entered the furnace mingled with the air. The air from the small blower served to support the combustion of the oil, and then, at a high temperature, mingled with the cold air of the large blower. The stove was tried several times, and appeared to hinder rather than to help combustion, a result which may have been due to the silicious slag used. Where it had formerly been tried at the Omaha & Grant works, it worked for several days, and it was considered that the success in the latter case was due to the more basic slag used.

The blast furnace was arranged with the bustle pipe below the tuyeres so that, when they were slagged, the molten slag ran down into the bustle pipe, partly filling it. The furnace was charged

through the feed slit by means of a car 10 feet long by  $2\frac{1}{2}$  feet wide, which dumped automatically into the furnace, but it was later arranged to dump upon the feed plates, and the charge was fed in by hand. When dumping automatically a shutter was arranged which served to deflect the ore to either side of the furnace to ensure even charging. The size of charge finally settled upon was nearly three tons, and it was not observed that the furnace worked any better when using small charges. The furnace bosh was about 12" both side and end, and the air escaped more quietly from the surface of the charge in consequence.

In this particular case cheapness of operation called for the smelting of the charge raw, sulphides and all. For all this it was a surprising fact that a high concentration was attained of at least 20 of charge into 1 of matte. The slag was silicious (40% to 45% silica), and was remarkably clean. When the copper on the charge was low, say  $\frac{1}{2}$ %, the silver was a little high in the slag, but it contained less than  $\frac{1}{10}$ % copper and no gold, while the silver ran as low as 0.6 ounce per ton.

The ore, as already stated, was stored in bins with discharging gates, and, consequently, the charge varied greatly in fineness and in composition, a condition opposed to close work in smelting. The furnace ran slowly on the silicious slag used.

The forehearth, about  $4\frac{1}{2}$  feet cube inside, was lined at first with basic or magnesia brick. For our conditions this was a needless refinement. The forehearth made a clean separation, but otherwise it soon became obstructed. The neck joining the forehearth to the furnace also became obstructed by the gradual formation of a zincky crust. It was finally decided to abandon the original method of operating it where a crust was made above the level of the neck, and it was then changed to work like the ordinary forehearth. This permitted proper access to the interior of the furnace. The original method referred to above has been entirely successful in Arizona, where a large amount of charge goes through the furnace, and where much matte is used. In fact, there the

endeavor has to be to retain the matte from breaking out rather than to have the forehearth fill up.

The water jackets used are patented, and are built by the Colorado Iron Works. The jacket water is not simply heated and allowed to run to waste, but is evaporated, so that only one-tenth as much is needed to cool the jackets. They require but little attention.

Mr. Kirby: What was the composition of the matte?

Mr. L. S. Austin: Between 5% and 10% in copper. The zinc in the slag amounted to 6%.

Mr. W. L. Austin: What per cent of fuel was used?

Mr. L. S. Austin: Seven or 8% of the charge, exclusive of foul slag returned to the furnace. Experimentally coal was substituted in part for the coke, but it had not been used long enough to say whether it was an advantage to do this.

Mr. W. L. Austin: What amount of raw  $\text{FeS}_2$  was used?

Mr. L. S. Austin: From 25% to 33% of the charge.

Mr. Kirby: Were these results obtained while using hot blast?

Mr. L. S. Austin: No; they were obtained while using cold blast.

Mr. Livingstone: My experience while using the apparatus at the Omaha & Grant works, of this city, was that it pumped oil into the furnace.\*

Mr. W. L. Austin: The oil of the stove must have burned the life out of the air, or it would not have blackened the tuyeres. In Pennsylvania a man tried to use oil for fuel, pumping it into the tuyeres. It always put out the furnace.

Mr. Kirby: I saw the same thing at the South Chicago Steel works, and it was a failure, though I did not learn why.

Mr. L. S. Austin (to the President): What has been your ex-

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\*The blast stove used at Buena Vista was an improvement on the earlier one, and burned the oil more completely, so that the objection urged by Mr. Livingstone would hardly apply.—L. S. Austin.

perience using the ordinary hot blast, with respect to blackening of the tuyeres?

Mr. W. L. Austin: With basic slags the hot blast brightened the tuyeres, but with slags of 40% silica and over, they became black in spite of the hot blast, even at temperatures of 800° to 1,000° Fahr.

Mr. L. S. Austin (continuing his remarks): The stack was at first too low, rendering it impossible to operate the furnace, because of smoke and fumes on the feed floor. The stack was thereupon raised some 15 feet more, which increased the draft so that the smoke was readily removed.

The motor was a constant-speed one, and therefore unsuited to driving blowers. As a temporary expedient for regulating the speed, a resistance tub was used. This was a fibre wash tub filled with water, in which was suspended two terminal copper plates of about 12 inches square. By approximating or separating the plates, the resistance was correspondingly varied, and, with it, the speed of the motor. The water evaporated at the rate of about 20 pounds per hour, and was constantly replaced. Some salt was added to the water to diminish and equalize the resistance.

Mr. W. L. Austin. - Where the slag used contains 30% silica, there is no difficulty in operating a Herreshoff forehearth, such as has already been described. The neck is made only 2" long, and it has been found to freeze when 6" or 8" long. When accretions form in the forehearth, as a consequence of using a silicious slag, they can be cleared out by using a basic slag.

Mr. Kirby: Was the accretion which formed at the Buena Vista furnace, chilled slag or a sulphide deposit precipitated from the matte?

Mr. L. S. Austin: It was chilled slag.

Mr. W. L. Austin: You must have obtained a good deal of heat from the burning of the sulphides in this furnace, or else it would not have been possible to run with so little fuel?

Mr. L. S. Austin: Had it not been for that I would have used

at least 12%. At the South Dakota furnaces, where they run on a 52% silica slag, they use 12% to 16% coke.

Mr. W. L. Austin: At Butte they have run their furnaces, using a slag containing 60% silica.

Mr. Kirby: How does the matte settle?

Mr. W. L. Austin: Very well indeed.

Mr. Livingstone: At Dr. Carpenter's furnace, in South Dakota, the slag chills so rapidly that the pots cannot be dumped.

Mr. W. L. Austin: In California, a man smelted silicate of magnesia with lime in an iron cupola, made a very fluid slag, and produced metallic nickel.

Mr. Livingstone: Dr. Carpenter used dolomite, making a silicious magnesia slag, and made iron sows very rapidly.

Mr. W. L. Austin: He could get rid of those by using iron pyrites. In Arizona, a brick furnace having the usual contracted top, made flue dust at a fearful rate. The top was altered, being built up straight, and but little flue dust was made, and, moreover, the old flue dust was returned to the furnace, and was smelted up with little further trouble.

Mr. Livingstone: The mechanical loss (flue dust) may be reduced in this way, but the *fume* in the case of the lead furnace will carry through the flues to a distance of 2,000 feet or more.

Mr. Henry A. Vezin:—Freiherr von Weber,\* in describing an invention by Dumery, calls attention to the fact that, if air diluted with nine times its volume of products of combustion, is mixed with combustible gases, the latter will not burn, no matter to what degree the mixture may be heated. It is probable that a much less dilution would be sufficient to prevent combustion. It is well known that men can live in an atmosphere in which a candle goes out. I do not know how great the dilution is in such a case; probably much less than equal parts of air and products of combustion. If the gases from the oil flame are dissociated, even only

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\*The Smokeless Combustion of Stonecoal with Special Reference to the Invention of C. J. Dumery. By M. M. Freiherr von Weber, Leipzig, 1859.

in part, the cooling effect described would be accounted for. Should these gases by any chance reunite higher up in the furnace, the heat produced would be carried where it is not wanted.

Mr. Kirby: Dissociation of  $\text{CO}_2$  and dilution of air, are sufficient to account for observed facts.

Mr. Livingstone: At the Omaha & Grant works we burned three barrels of oil per day, and reduced the charcoal from 140 pounds per charge to 90 pounds. The current of air was such that we forced unconsumed oil into the furnace. Another experiment of the Colorado Iron Works, at our works, was an attempt to cool a jacket by air only. It burned out in an hour.



## SAMPLING OF ORE IN PLACE.

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Meeting of January 3, 1898.

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### DISCUSSION.

**Mr. J. A. Porter.**—More errors are made in this work than in any other branch of the mining engineer's profession. Many cases in which great errors were committed, have come to my personal knowledge. Too much care cannot be taken. As a rule samples are neither sufficiently large nor sufficiently numerous, and instances are not wanting where the expenditure of half a million dollars depended on samples aggregating fifty or sixty pounds.

When an ore body is to be sampled, all regular work in the mine should cease, and the examining engineer should have entire charge of the property. At least three independent samples should be taken, and they should involve tons, not pounds. Even in very homogeneous veins, a sample should be taken every ten feet of length, and in gold mines nothing short of an actual mill run can be relied upon. I regard the sampling of an ore body as of more importance than the sampling operations on the results of which ore is sold, as the former usually involves the transfer of a much larger sum of money than the latter.

**Mr. W. L. Austin** cited a case in his experience in which the mine samples, though taken with the greatest care, gave persistently higher results than could be obtained at the mill. At the mine samples were taken from the working faces in the stopes, and a hand sample was taken from every car of ore brought out of the mine. The results showed an average of about one hundred ounces of silver. At the mill the bullion returns plus the tailings

assays showed only about forty odd ounces. Mr. Austin explained this discrepancy as follows: The valuable portions of the ore were chiefly chlorides, bromides and other extremely brittle minerals. The picking and gadding necessary in breaking down rock for the sample, jarred large quantities of these brittle materials out of the rock which was left in place, and these fell upon the cloth spread below, so that the engineer unconsciously "salted" his own sample.

Mr. Austin thought that the results of mine sampling with certain classes of ore, even when the work is carefully done, are almost invariably too high, and that small hand samples are, in many cases, comparatively worthless.

**Mr. Henry E. Wood** said that he believed hand samples properly taken by a person who understood such work, to be perfectly reliable. He thought that the expense attached to the method of sampling suggested by Mr. Porter would be prohibitory in very many instances.

**Mr. E. Le Neve Foster.**—This is the most difficult work we have to do. The general experience is that estimates based on samples far exceed the results obtained in the subsequent working of the mines. The engineer frequently deceives himself. In attempting to include a fair proportion of the more valuable ore, he often gets too much. In silver ores the most brittle portions are the richest, and, in sampling, we are very likely to get too large a proportion of this material in spite of the great care exercised. I think it is necessary to break at least one hundred pounds of ore at each place where a sample is taken, and then quarter this down to a convenient amount. In estimating the value of a mine which has been worked to a considerable extent, the safest plan is to base the estimate on previous sales of ore. Even this method must be used with some caution, as it is very probable that the richer portions of the vein have been worked out, and the poorer ore left.

**Mr. Henry A. Vezin** thought that there was no difficulty in making sufficiently accurate samples of ore in a mine, if the examiner

would only take the trouble to follow a simple system, consisting of purely mechanical methods, instead of using what he is pleased to call his judgment, which generally consists in picking out a sample by judging of its value by the eye. He agreed entirely with Mr. Porter that the trouble lies in the sampling, improperly done. When a slice is taken at any one point it should be deep enough to take as much of the hard as of the soft, and these slices should be taken at sufficiently short intervals and in sufficiently large number.

Mr. Vezin understood that this meeting was to take place on the 8th instead of on the 3d, and was only able to give a few examples, from memory, instead of more accurate data that he intended to look up.

The first example is that of the sampling of a mine from which good results had been expected. His assays of ore that had been brought to the smelting works for treatment, gave such low results that his ability as an assayer was seriously called into question, the value being scarcely one-fourth of the estimates previously made, all of which were based upon the results obtained from treating several hundred tons of ore. The mining captain, a very careful man, was ordered to take samples of the vein, and he brought ten of these as the result of five or six hours' work. Mr. Vezin objected to the method employed, but was told by the manager, who did not consider that his opinion, he being merely the assayer, could be of much value, that what he required in sampling the vein would make each sample cost \$60.00. He thinks that \$6.00 would have been more than enough, but, assuming even that the other estimate was correct, the total expenditure would have been \$600, and it would have resulted in saving the subsequent expenditure of \$600,000, besides avoiding a great deal of heart-burning and bitter disappointment. The result from these ten samples showed a value more than twice as great as that which the ore yielded when treated in the works.

The second example was that of a mine opened up by 500 feet to 800 feet of drift and winzes, which was to be examined by the

metallurgist who expected to smelt the ore. Wishing to make the examination on the way from one mining town to another, a distance of about sixteen miles, with a high range between, and complete the investigation all in one day, he took all the samples, while Mr. Vezin made the map of all the openings. The result obtained by the metallurgist was 30 ounces of silver to the ton as the average. Later, when he had partly completed the smelting works, and brought down lots of 20 and 50 tons of ore, he found that it uniformly contained 11 ounces to the ton, and then admitted that he had made the mistake by simply taking the average of his samples, to which may be added that he did not take enough at each place.

Third example: In Mr. Kirby's very interesting paper on sampling at mines, read before the Society in 1894, the weight or influence given to one or a few samples is, Mr. Vezin thought, much too far-reaching. Adapting some of Mr. Kirby's rules, as he remembers them, to the ore bodies in Leadville, the result can only be disastrous, as was the case when a distinguished mining expert was examining a mine for intending purchasers in the East. Taking the map as made by Mr. Vezin at that time, and then drawing lines across as limiting probable ore shoots, determined by the thickness of the ore at two points far apart, cutting down this thickness to one-half or a quarter, and assuming the value much less than he supposed he had found, then measuring the surface of the shoot "by the acre," he obtained a value of ore in sight three or four times as great as that which was afterwards taken out up to the time when the mine was exhausted.

Fourth example: In examining some mines in southwestern New Mexico, Mr. Vezin followed the simple method of taking sufficiently thick slices from the vein at regular intervals. The ore was a very hard quartz, with gold and silver irregularly distributed through it. The samples had to be broken up by hand-hammers and gradually reduced. The quantities taken were very much smaller than those suggested by Mr. Porter, and the result was so close that nobody ever found more in the vein after Mr.

Vezin had made the examination, though his result was less than one-half of what anybody else had found before. He was able, with two miners, to take and reduce in quantity three or four samples per day. The average was about \$20.30 per ton. As a precaution against salting, the rejected portions of the samples were thrown together, each one being measured by the number of shovelfuls, as there was no means of weighing the same. These portions were mixed, cut down, crushed, the average value of the same determined by calculation, and the sample of the whole lot also assayed. The assayer's return gave a value of \$17.80, while by calculation with the crude method of measurement adopted, the average was \$21.60. The arithmetical mean of the values of the samples, of which there were ten, was \$20.60, or nearly exactly the same as the value by the calculation. Owing to the nature of the ore it is quite likely that \$21.60 was much nearer to the true value than the return by the assayer of the sample of all the rejected portions. A re-assay of this might give a somewhat different result. The main thing is that his return showed that there could have been no salting of any of the samples. These results, of course, do not necessarily show the average value of the vein, since the thickness of the same, which varies from 14" to 44", was not brought into the calculation in the rejected portions. That the average of the vein and the value of the rejected portions should be so nearly alike, is purely accidental.

Mr. Vezin does not think that it requires any extraordinary intelligence or skill to obtain approximately correct samples. Any handy man can be taught how to do so, and in a few lessons. All it requires is care and patience. He regretted that Mr. Hills, who could give some interesting examples of his own experience in Utah, and Mr. Argall, were not present. The latter spent a few days with a very able miner as assistant, in sampling a mine in southwestern Colorado. The ore consisted principally of gangue, with gold, silver and a few finely divided sulphides of iron and zinc. The value which was reported to the prospective purchasers was, if I remember rightly, only 9 cents higher than that which was actually

found when the ore was subsequently taken out and treated, its contents being about \$10.00 to the ton. That is most extraordinary. Mr. Vezin thought that if he could come within 10 or 15 per cent. of the actual value he was doing remarkably well.

As regards Mr. Austin's experience, he could only say that the man who made the mine samples had not the vaguest notion of how to do it. As a matter of course, when a vein consists of various streaks, each one should be determined by itself in case each should be treated by itself, so as to determine where the values are, but always after the same method.

Much time can be saved by little conveniences which can be taken to mines in out-of-the-way places, so as to reduce the labor of crushing and cutting down, and enabling the examiner to do this himself, and thereby guard against that which he has most to fear, the salting of the material.

**Mr. J. A. McClurg** mentioned an instance in his experience in which the working of a mine resulted in only about one-half the tonnage estimated at the time of the examination.

**Mr. G. M. Gonyard.**—In some cases, the high results obtained from samples were due to sorting, whether intentional or not, of the rock broken down by the men who were set to break it up so that it might be quartered. They frequently found it easier and simpler to throw out a large piece of quartz than to break it into smaller sizes.

**Mr. E. C. van Diest.**—The sampling of prospects is a much more difficult matter than that of developed mines.

Cases might arise where the purely mechanical method recommended by Mr. Vezin would fail to give fair results. Cases were cited in which he had attempted to sample veins containing streaks of different minerals of very different hardness, by this method. He found it impossible to get the proper proportions of the different materials, as evidenced by the fact that three samples from the same place, taken with equal care, gave widely differing results. In such cases, it is much more reliable to sample the different streaks separately. An instance worthy of mention is

where, after taking samples in the mine, he sampled the ore dump by digging trenches across it in various directions. The result of the dump sample was about one-third that of the mine sample. He subsequently ran eighteen tons through a mill, and the returns differed only seventy-five cents per ton from the result of the dump sample.

# THE ANDESITE OF MOUNT SUGAR LOAF, BOULDER COUNTY, COLORADO.

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By **BARRY HOGARTY.**

Department of Chemistry, University of Colorado.

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Meeting of March 4, 1899.

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Sugar Loaf Mountain is situated about eight miles west of the city of Boulder, and about two miles north of the 40th parallel, between Four-Mile and Boulder Creeks. The immediate vicinity is known as the Sugar Loaf Mining District, the ores of which are of the telluride type.

The region in which it is located, viz., the elevated part between the foot-hills and the main range, has, in its larger aspect, the general appearance of an eroded table-land. Nevertheless, the mountain itself, which is about 8,000 feet in height, is rather isolated, and suggests the appearance of an eroded laccolitic cone. There is no evidence of a crater. The top and the slides on the sides of the mountain, down for about eight hundred feet from the apex, consist entirely of this andesite in irregular slabs, usually less than one foot in diameter, and as a rule the fragments are largest on the top.

So far as known, no outcrop of this rock has shown the contact with the regional granite; neither is there any evidence in regard to the age of eruption. No rocks related to this have yet been traced out, but probably there are some to the north and west. About two miles west of Sugar Loaf Mountain there is situated a hill, which is composed of a rock that has a strong resemblance to this andesite, except in that it is apparently very



much coarser grained, both as regards phenocrysts and ground mass. This rock has not been investigated as yet, but in all probability it will be found to be related to the Sugar Loaf andesite.

The eruptive rocks of Boulder County have furnished material for continuous analytical work for this laboratory; and this paper may be regarded as a part of that series, with the incidental interest in the question of any possible relation between this rock and the ore deposits of the immediate vicinity.

Mr. S. F. Emmons, of the U. S. Geological Survey, examined this andesite in 1880, and reported as follows:

\*"Of eruptive rocks, that which forms the Sugar Loaf, a conical hill between Four-Mile and Boulder Creeks, is a fine-grained, porphyritic rock of a grayish color, showing, in the hand specimen, small white feldspars, biotite, hornblende and titanite, the latter of a yellow color, being quite frequent.

"Under the microscope the rock shows some augite and a crystalline ground mass containing a little quartz, but is made up mainly of feldspars in rounded particles not sufficiently well-defined for determination."

From the above, it would seem that the examination was made rather hurriedly. I was unable to find reference to any analysis of the rock, and I believe that none has yet been published. Neither have I found any detailed reference to the material of the mountain cap in any of the literature.

#### MEGASCOPIC EXAMINATION.

The rock is of a brownish-gray color, and weathers to a dull reddish-gray. It has a subconchoidal fracture, and, in large specimens, has a characteristic metallic clink on being struck. The undecomposed rock shows small white and pink feldspars, amphiboid and pyroxenoid minerals, a dark mica in black, shining scales, and titanite of a honey-yellow color.

The specific gravity of the rock, as determined by direct displacement of water, is 2.568.

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\*10th Census Report, Vol. 13, page 65.

## MICROSCOPIC EXAMINATION.

## A. The Phenocrysts.

I found the following phenocrysts, and their relative abundance, approximately estimated by the careful counting of many fields in several sections, as follows:

Feldspar about 20 per cent. (orthoclase and sanidine being 13 per cent. and the plagioclase 7 per cent.).

Hornblende about 2 per cent.; pyroxene about 5 per cent., a little less than half of this last being augite.

Biotite about 3 per cent.; magnetite 3 per cent. Both apatite and titanite are found, but in very small amounts.

This estimate gives approximately 33 per cent. for the phenocrysts leaving about 67 per cent. for the ground mass.

*The Orthoclase.*—This is of two varieties, viz.: orthoclase proper and sandine. The former, which composes about 9 or 10 per cent. of the whole rock, occurs in well-defined crystals of a maximum length of two to three millimeters. Twinning according to the Carlsbad law is very common; also, a zonal banding (suggesting an increasing acidity of the ground mass during the growth of the crystals) is quite common. In a few instances I noticed the presence of a "globulaire rim." Some kaolinization has taken place within the body of the crystal, and sometimes this is distributed throughout the whole crystal. The inclusions are mainly apatite, of a length not more than three or four hundredths of a millimeter; with some gas inclusions and strings of margarites and other microlites.

*The Sanidine.*—Which forms about 3 or 4 per cent. of the rock, occurs in tabular glassy crystals of a length not to exceed one and one-half to two millimeters. This is colorless, in thin sections, usually in Carlsbad twins, and often interwoven with the plagioclase feldspars, forming an "anorthoclase" growth. The zonal banding is also quite noticeable in the sanidine. The inclusions are apatite needles and other microlites.

*The Plagioclase.*—This forms about one-third of the total

feldspar; it occurs in well-defined crystals from one and one-half millimeters in length and one-half millimeter in breadth, down to one-fourth of these dimensions. The albite and pericline twinings are very common, being clearly noticeable under cross nicols. The extinction angles seem to be approximately those of andesite and labradorite. The zonal banding and the kaolinization are less marked in the plagioclase than in the orthoclase. The inclusions of the plagioclase are essentially the same as those of the orthoclase.

*The Hornblende.*—This appears to be the eruptive hornblende usually found in hornblende-bearing andesite. It forms approximately 2 per cent. of the whole rock; the crystals, which are well-defined and about two or three millimeters in length and three-fourths of a millimeter in diameter, are of a brownish-green color, strongly pleochroic, and have a dark border of magnetite grains. This last may represent a reaction between the hornblende and the groundmass. Basal sections show distinctly the characteristic cleavage. Occasionally this mineral occurs twinned, the twinning plane being the plane of composition, which passes through the center of the crystal parallel to the orthopinacoid; this does not alter the crystal form. Inclusions of apatite are very sparingly present.

*Pyroxene.*—This is of two varieties—augite and another variety which I was unable to identify. The latter I will designate, for convenience, as *green pyroxene*, as distinguished from the augite proper.

*The augite* forms about 2 per cent. of the rock; it occurs in fresh granular crystals of four or five tenth-millimeters in their greatest diameter, and easily identified by the characteristic cleavage. Cross-sections are octagonal in form, bright yellowish-green in color and slightly pleochroic, as is usual with the augite of andesitic and trachytic rocks. Under ordinary light it has nearly the same color as the green pyroxene, but is more strongly pleochroic. This is occasionally twinned, the twinning plane being parallel to the orthopinacoid; also, according to another law, where

the twinning plane is parallel to the clino-pyramid (122). In the former case the outline of the crystal section is not altered; in the latter the twinning produces lamellæ.

Inclusions of apatite needles are very sparingly present.

*The Green Pyroxene* (other than augite).—I had much difficulty in determining this, and am still in doubt concerning it; however, it belongs to the pyroxene group, but to what particular variety I am unable to state. It forms about 2 or 3 per cent. of the whole rock, occurring in irregular elongated crystals, the length being three or four times greater than the width, and without definite end termination. Usually they do not exceed one millimeter in length.

This pyroxene is of a light green shade, scarcely, if at all, pleochroic, and polarizes in high colors. The extinction angle of the longitudinal sections is high, being from thirty-five to forty-five degrees.

I first considered this to be a secondary hornblende; but there are no special evidences of decomposition; it does not possess the granular border of magnetite as in the case of the hornblende; and furthermore it will be noticed that the pleochroism and the cleavage of the latter are entirely wanting. Also the angle of extinction is too high for hornblende, and there is no evidence of chlorite. Orthorhombic pyroxene is wholly absent.

*The Biotite*.—This, the only mica present, forms approximately 2 or 3 per cent. of the whole rock, the crystals, usually not more than one-half a millimeter in diameter, are irregular, and possess a granular border of magnetite. They are brown to black in color, and strongly pleochroic. Apatite needles are the only inclusions.

*The Magnetite*.—This forms 2 or 3 per cent. of the whole rock, the crystals being well defined, and not more than two or three-tenths of a millimeter in diameter. Occasionally the groundmass surrounding the magnetites is colored brownish by the decomposition of the magnetite to ferric oxide.

*The Apatite*.—This forms only a very small percentage of the

whole rock, usually occurring as inclusions, although a little was found in the groundmass. It is always in fine needles, three or four hundredth of a millimeter in length.

*The Titanite.*—This also forms a very small percentage of the rock. The crystals are of a honey-yellow color, have the characteristic wedge-shape, are highly refractive, and very fresh.

There is no indication of a grouping of the titanite crystals near the hornblende or other phenocrysts, *i. e.*, they occur in as complete isolation as any of the larger crystals. The larger ones are usually about one-half a millimeter in their greatest diameter, though a few are large enough to be seen in the hand specimen, and there are a few very fine ones in the groundmass.

#### B. The Groundmass.

Under a one-sixth objective, this appears to be an ill-defined crypto crystalline (microfelsitic) base, made up mainly of irregular granular crystals of feldspar of a hypidiomorphic outline, and possibly carrying a few grains of quartz. The general character corresponds approximately to the "pilotaxitic" structure of Rosenbusch.

Under a higher power (one-tenth immersion\*) the groundmass is clearly resolved into a mass of semi-regular crystals of feldspar, approximately one-thirtieth by one-hundredth of a millimeter; they do not seem to possess sharp boundaries, for while one crystal, in its main portion, under crossed nicols, may extinguish as a whole, yet the light shades, or shimmers off into the region of the neighboring crystal, which latter, as a whole, has an extinction angle clearly distinguishable from that of the first. The structure would seem to be clearly a case of advanced devitrification. It is possible that the ill-defined boundaries and the shimmering between crystals may be due to the scanty remnants

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\*It is not customary, perhaps, to use immersion lenses in petrographic work, but in the case of an obstinate base or groundmass, it is a great assistance. The laboratory is indebted to Mr. R. C. Hills for the valuable suggestion. See, also, Palmer and Stoddard, "The Dike on the Columbia Vein in the Ward District, Boulder, County, Colo."—*Proceedings of Colorado Scientific Society*, Vol. 5, page 162.

of the glassy base, which should be quite acid as compared with the rest of the rock; or this appearance may be partly due to this and partly to a quartzose cement.

The irregular shimmer under crossed nicols, between and connecting the different crystals, is suggestive of glass under tension. These micro-crystals have no clear outline, yet they extinguish regularly by comparison with the direction of their greatest length. In fact, the appearance is as though each micro-crystal were surrounded by an irregular "globulaire rim" of glassy origin, this glassy globulaire rim being partly dominated in common by all of the immediately contiguous crystals, and yet there are only a few well-defined remnants of the glassy base. But the subject is an obscure one, and I shall not attempt a description of that which has been a subject of controversy among petrographers.

The micro-crystals carry many inclusions. Apparently very few of these are of a glassy character. There are some indications of kaolinization.

#### THE ANALYSIS.

The sample was selected from the undecomposed rock. Throughout the analysis I followed Dr. Hillebrand's valuable "Methods of Silicate Analysis,"\* which were found to be suitable, expeditious and accurate. Double precipitations were resorted to in all cases except in the determination of magnesium.

Water was determined by direct absorption with sulphuric acid.

Phosphoric anhydride was determined in a separate portion. It was first precipitated as ammonium-phospho-molybdate, then dissolved and reprecipitated, and finally weighed as magnesium pyrophosphate.

Titanium dioxide was determined also in a separate portion, by colorimetry. It was first oxidized by hydrogen peroxide, and then compared with a standard solution of titanium sulphate simi-

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\*Bulletin 148, U. S. Geological Survey.

larly treated. The small amount of iron present could not appreciably affect the result.

The alkalis were determined by the J. Lawrence Smith method, the potassium being weighed as potassium platonic chloride. The soda was determined by difference, calculating from the total alkalis weighed as the chlorides.

For ferrous oxide I decomposed the rock with hydrofluoric and sulphuric acids in an atmosphere of carbon dioxide, and titrated with a standard solution of potassium permanganate.

The silica was determined by the loss upon evaporation with hydrofluoric and sulphuric acids; the residue, consisting of one or two milligrams, was fused with acid-potassium sulphate and added to the main solution. The trace of silica, which always accompanies the aluminic and ferric oxides, was removed by fusion with acid-potassium sulphate and added to the main portion of the silica, in calculation.

The total iron was reduced and titrated by a standard solution of potassium permanganate.

The alumina was determined by difference, after deducting the titanium dioxide, phosphoric anhydride, ferric oxide, and ferrous oxide calculated as ferric oxide.

Manganous oxide was determined as the pyrophosphate.

Calcium oxide was precipitated as the oxalate, and finally weighed as oxide.

Magnesium oxide was determined as the pyrophosphate.

There was a trace of sulphur present.

Besides the ingredients mentioned above, the following were tested for, with negative results, viz., the metals the sulphides of which are insoluble in hydrochloric acid solution; and also lithium, barium, strontium, chlorine, fluorine and carbon dioxide.

The presence of apatite in the rock would indicate that either fluorine or chlorine is present; but with the small amounts worked with, no traces were found.

## THE ANALYSIS COLLATED.

Silica .....	63.64
Titanium dioxide.....	.43
Alumina .....	18.06
Ferric oxide.....	2.14
Ferrous oxide .....	1.80
Manganous oxide.....	.46
Calcium oxide.....	3.36
Magnesium oxide.....	1.01
Sodium oxide.....	3.65
Potassium oxide .....	4.73
Phosphoric anhydride .....	.18
Water.....	1.07
	<hr/> 100.52

In addition to the tests for the traces of ore-forming metals, a special test was made on about fifteen grams, for the presence of tellurium, zinc, sulphur, etc., only traces of the latter being found. This would indicate that if the porphyritic rock is the home of the ores of the neighboring region, they must be present only in very sparing quantities.

## THE DISCUSSION OF THE ANALYSIS.

I shall here attempt roughly to distribute the constituents among the different minerals as they may be fairly supposed to exist in the rock. As the silica, alumina, and alkalies and lime are the principal ingredients, I shall consider them first.

*The Silica.*—The orthoclase, which was estimated at 12 or 14 per cent. of the rock, would carry approximately 7 or 8 per cent. of the total silica. This was obtained simply by taking the product of the percentage of orthoclase, and the percentage of the silica in the orthoclase.

In a similar manner the plagioclase, which was estimated at 6 or 8 per cent. of the rock, would account for from 3 to 5 per cent. of the total silica.

The other phenocrysts, viz., hornblende, augite, pyroxene, biotite, magnetite, and sphene, which together form 10 or 12 per



cent. of the rock, will account for approximately 5 or 6 per cent. of the silica. This makes a total of about 17 per cent. of the silica in the principal phenocrysts, leaving about 46 per cent. of silica to be carried by the groundmass; this latter forms about 66 or 68 per cent. of the rock, giving it an acidity of about 70 per cent., as compared with the 63 per cent. of the average rock.

*The Alumina.*—Again, the orthoclase accounts for about 2 or 3 per cent. of the alumina, and the plagioclase probably carries from 1 to 3 per cent. of it. The other phenocrysts would probably not carry more than 1 or 2 per cent. This would leave 10 or 12 per cent. of the total alumina for the groundmass; and this would indicate that the alumina forms about 16 per cent. of the groundmass, considered by itself. This means that the groundmass contains plenty of this ingredient of feldspar; and that mineral has already been indicated there.

*The Alkalies and Lime.*—In a similar manner it is found that the phenocrysts probably carry about one-half of the potash (mostly in the orthoclase and sanidine); about one-fourth or one-fifth of the soda (mostly in the plagioclase); and about one-third of the lime, the last being in the plagioclase and in the ferro-magnesian minerals. This would indicate that the groundmass carries also an abundance of alkaline material for feldspars, as already indicated.

*The Iron Oxides.*—The oxides of iron correspond approximately to the quantity of magnetite and ferro-magnesian minerals present as phenocrysts.

*The Titanium Dioxide and Manganous Oxide* may be accounted for in the sphene, in the magnetite, and in the ferro-magnesian minerals.

## THE ACTUAL ANALYSIS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Silica .....	63.43	63.72	63.78									
Titanium dioxide.....				.42	.45							
Alumina .....	18.09	18.01										
Ferric oxide.....	1.79	2.38	2.26									
Ferrous oxide .....						1.87	1.73					
Manganous oxide.....	.58	.35										
Calcium oxide.....	3.43	3.26										
Magnesium oxide.....	.98	1.03										
Sodium oxide .....								3.65				
Potassium oxide.....								4.73				
Phosphoric anhydride .....									.17	.18		
Water.....											1.06	1.08

This would indicate roughly that the composition of the groundmass is as follows:

Silica from 68 to 70 per cent.; alumina from 16 to 18 per cent.; potassium oxide from 2 to 3 per cent.; sodium oxide from 2 to 3 per cent.; calcium oxide about 2 per cent.

From this it would seem that the groundmass is more acid than any of the phenocrysts, and, in fact, this is just what we should expect in a rock of this character. Also the silica in the groundmass appears to be in excess of that which should combine with the alumina and alkalies to form feldspar; and this suggests that the cementing material, spoken of under the groundmass, may be either quartz or a very acid glass. On the whole, the microscopic examination and the analysis seem to be in keeping with each other.

#### COMPARATIVE ANALYSES.

A careful search was made in the available literature for such andesites as might resemble in appearance, or in chemical or mineral composition, the rock described in this paper. But nothing was found showing resemblance both in appearance and also in chemical composition. However, I take the liberty to quote, in comparison, some analyses of western andesite which, in composition, closely resemble the andesite of Mount Sugar Loaf. They are as follows:

No. I. "Pringle Andesite" from a dike, Rosita Hills, Custer County, Colorado. The analysis was made by L. G. Eakins. (U. S. Geological Survey, Seventeenth Annual Report, Part II, page 263, by Whitman Cross.)

No. II. Hornblende andesite from Mount Rose of the Washoe District. Analyst, R. W. Woodward. ("Geology of Comstock Lode and Washoe District," Vol. 17, page 152, G. F. Becker.)

No. III. Mica Andesite, from the Eureka District, 800 feet east of Waller Defeat Shaft. Analyst, Gideon E. Moore. ("Ge-

ology of the Eureka District, Nevada." House Documents, Vol. 53, page 282, by Arnold Hague.)

No. IV. Andesite from Sugar Loaf, Boulder County, Colorado. Analyst, B. Hogarty.

	<i>I.</i>	<i>II.</i>	<i>III.</i>	<i>IV.</i>
Specific gravity .....	2.69	2.5 to 2.4	.....	2.56
Silica .....	63.49	63.30	65.68	63.64
Titanium dioxide .....	trace	.....	0.98	0.43
Alumina .....	18.40	17.81	15.87	18.05
Ferric oxide .....	2.44	3.42	1.87	2.14
Ferrous oxide .....	1.09	0.83	1.25	1.80
Manganous oxide .....	0.16	.....	.....	0.46
Calcium oxide .....	2.30	5.12	3.50	3.36
Magnesium oxide .....	0.66	2.07	1.79	1.01
Potassium oxide .....	4.62	2.26	3.37	4.73
Sodium oxide .....	5.70	4.27	3.20	3.65
Water .....	1.04	0.88	3.10*	1.07
Carbon dioxide .....	trace	.....	.....	.....
Phosphoric anhydride .....	trace	.....	.....	0.18
Total .....	99.90	99.96	100.61	100.52

\*Ignition.

In closing, I wish to acknowledge my indebtedness to Prof. Charles S. Palmer, whose suggestions and assistance in the work here presented have been invaluable.

## METHODS OF TESTING AND SAMPLING PLACER DEPOSITS.

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BY EDMUND B. KIRBY.

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Meeting of April 1, 1888.

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Every engineer who has had to do with placer work, realizes how difficult it is to ascertain, even approximately, the average gold contents of gravel.

The problem presented often comprises gravel beds measured by hundreds of acres, or by miles of gulch bottom. The quantities which it is possible to use for actual tests, whether measured by panfuls or by thousands of cubic yards, are but a minute fraction of the great bulk. Moreover, the distribution of gold in this mass is irregular and uncertain to an extreme. From the nature of the deposit, only small portions of it, at best, can be rich enough for pay. These local enrichments are due to the concentrating action of the stream at intervals during its long history. They are, therefore, subject to all the irregularities which might be expected from its ceaseless shifting, and the changes in the material deposited.

Notwithstanding these difficulties, a business decision is called for, and it is always necessary to reach a sound conclusion without expending more time and money than the circumstances warrant. In most cases, therefore, it is best, if possible, to carry on the work by successive steps. If the general evidence examined proves satisfactory, it affords a basis for proceeding to the more simple and inexpensive tests. Encouragement from these will warrant more costly test workings, and the latter may be followed

by the heavy and decisive test work which is to settle the question at issue.

#### THE STRUCTURE OF GRAVEL DEPOSITS.

In most cases presented throughout the West, the gold-bearing gravels are deposits from the present system of streams, and their form and position have probably been developed during the Quaternary period. The high gravels of the California ancient river system are of earlier date, and form a class by themselves. As compared with the more recent deposits they are limited in quantity, and differ radically in structure, character of the gravel, grades and methods of working.

Only the first-mentioned deposits are under consideration here. They may be conveniently classed as "high bars" (above water level), and "bottom gravel" (at and below water level). The high bars are remnants of beds which were deposited before the stream cut down its gulch or valley to the present depth. They were originally terraced, but have frequently been shifted or changed in external shape by erosion. They were the most accessible and easily worked deposits, and, generally speaking, are now very scarce.

The deep gravel filling the present gulch or valley bottoms below water level, constitutes the principal bulk of the deposits now remaining in every placer district. As a rule it is inaccessible without the aid of skilled engineering, modern appliances, and the use of considerable capital. Of late years these deep deposits have attracted much attention. This is on account of their abundance, and because of the possibilities which may follow their development. The uncertainties and difficulties of such work are very great. It has been best developed by "river mining" in California, and in various districts of the Northwest. During the last few years modern heavy mining machinery for excavating, hoisting and conveying has been brought into use for this work. Many mistakes have been made in its application, and most attempts of this kind have so far been financial failures. Steady

progress is being made in perfecting such apparatus, and there is without question a large field for its application to cases where the conditions are suitable.

It is clear that the climatic and other conditions under which a stream cut down its channel in the bed-rock, were different from those which prevailed while gravel beds were deposited in this channel. In the first case, there was a large volume of water, and probably steep grades. In the second case, both waterflow and grade must be less, and this is the condition which now prevails in our western rivers and streams. The present grades are generally less than 2 per cent., and the transporting action on large gravel, even in time of freshet, has almost ceased. The bed-rock is now protected from erosion by a more or less heavy bed of gravel, over the surface of which the stream flows. In many cases the processes of erosion and deposition have alternated frequently, and this accords with what is known of climatic changes during the Quaternary period.

The gravel beds are made up of several streaks or layers, some of which may be gold-bearing, while others are entirely barren. These layers have all the irregularities of stream-deposited gravel. They are sometimes quite uniform in thickness and value over considerable areas, as though spread out by floods. In other cases they form crescent-like overlapping streaks, varying greatly in gold contents, and indicating their deposition in side bars by the stream as it shifted its position. During the deposition of gold-bearing gravel, the light or scale gold is apt to be distributed very uniformly throughout the entire mass. The heavy gold, on the other hand, tends to concentrate out in special streaks or layers. It is a frequent occurrence to find rich layers on top of barren layers, and many facts indicate that, during the deposition of rich gravel, its gold contents do not work down through undisturbed gravel beneath. When pay gravel exists in a gulch, it is generally confined to a ribbon-like layer on or near the bed-rock. It is not likely that this is the accumulation of gold which has sifted down from the overlying mass. On the contrary, there is every reason

to believe that the bed-rock channel for a long period acted like a sluice. As the transporting power of the stream gradually lessened, its gravel was alternately moved, and then redeposited. This sluice action, with the repeated shifting and loosening of the first deposits, doubtless caused their gold to accumulate in the bottom layers.

This pay lead or bed-rock channel is usually of limited width, and meanders along the gulch, marking in general the course and width of the stream at the time. There may be two or more of these channels, and they are not necessarily in the deepest part of the gulch. They may be found higher up, along its sides, as portions of earlier channels, made before the bed-rock of the gulch was cut down to its present depth. In such a channel the distribution of gold is very irregular, but, on the whole, it seems to follow the rule so often observed, and is heaviest on the inner sides of bends. It is usually necessary to work the channel by a pit or open cut. It is a rare occurrence to find that the general mass of gravel filling the gulch will average enough for pay. The slope required for the sides of the excavation increases the proportion of this poor gravel, so that the pay lead must be rich enough to bring up the average to the pay point.

#### EVIDENCE AVAILABLE IN PLACER EXAMINATIONS.

A determination of the average value of gravel is only one of the numerous questions, both business and technical, which arise in a placer examination. It is often unnecessary, because the business decision to be made, may be settled by other considerations. Moreover, the books and records of an established placer enterprise will often supply the data necessary to estimate the value of the ground worked. The reliance to be placed upon such evidence is matter for special judgment in each case. Generally, actual tests must be made, and the evidence to be secured may be roughly outlined as follows;

I. General evidence derived from the history, records, facts



shown by prior workings and neighboring mines, structure of the deposit, etc., etc.

II. Evidence from sampling gravel already exposed. Such exposures may be found in surface gravel, natural banks and gullies, or prior workings.

III. Evidence from special test workings made for the purpose. These may include shafts down to water level, and such work may be made light or heavy as warranted by the circumstances, and the facts developed during its progress.

IV. Evidence from heavy and decisive test workings. In high bars this may merely include a more extensive system of test shafts and drifts in the dry gravel, but, in the water-bearing bottom gravel, such work is very difficult and expensive. This should not be a serious objection, in view of the heavy investment which will be necessary to open and work a deposit of this character. The very existence of a pay channel, to say nothing of its grade, is uncertain. To risk a large investment on mere chance, without first feeling the way by such preliminary work, is not a course which will appeal to sound business judgment.

On account of the expense of testing gravel, it is impossible to cover a large territory. In practice, all that can be done usually is to select the most promising and workable locality, and decide the question at issue by the value of this portion. The test workings should be so arranged as to define the shape and limits of the pay ground. In a large area or a thick mass, there is no better system than a number of shafts. A channel may be exposed by a cross-cut drift from a shaft, and a few cross-sections of this kind at different points should give a fair idea of what may be expected from it. Bottom gravel may be 500 to 1,500 feet wide, and the main difficulty at first is to locate the position of the bed-rock channel. It will generally be best to secure some evidence on this point before starting a shaft. There is no better way of obtaining this than by a line of drop drill holes which will give an approximate cross profile of the bed-rock, and will also give some evidence as to the presence of gold and the character of the gravel.

The units of measurement used for placer gravel vary according to the shape of the workable ground. In a thick mass it is the cubic yard. In a thin sheet, with the values on the bed-rock, it is customary to use a unit of area such as the claim or the acre. For a channel, a unit of length is preferred, giving the yield per 100 or 1,000 feet of length. The extreme irregularities of the deposit are always to be kept in mind, and figures of measurement (like those of value) are to be used with caution. In averaging the results of tests, each should be given a value proportioned to the volume of gravel which it is supposed to represent.

#### SAMPLING GRAVEL.

In practice, gravel for tests is conveniently washed, either by the pan, the rocker, or by small sluices.

In pan tests, at each point sampled, a number of pans of gravel are taken at uniform distances apart, down the exposed face of gravel. On account of the variations in the different layers, much judgment is necessary to do this properly. The bank may comprise stones of every size, and only the finer and richer material, filling the interstices between the larger stones, can be taken into the pan. The sample is therefore limited to material less than three or four inches in diameter. In most beds this pan size gravel ranges from 25 to 60 per cent. of the entire mass. This percentage should be estimated. It is not possible to calculate from it the value of this entire mass, because the larger stones are not barren. Much of the gold adheres to their surfaces, and fine gold seems to have a special tendency to do this. Hence, if a pan test shows 20 cents per cubic yard of fine material tested, and this represents only 50 per cent. of the mass, it is not correct to assume that the latter averages only 10 cents per yard. The test merely fixes an upper and a lower limit, and the real contents lie somewhere between the two; in this case, between 10 and 20 cents.

Careful hand panning collects fine and scale gold perhaps

more closely than any other practical method. It will be found best to wash down to the black sand, which is almost always barren, and then determine the gold by assay. One hundred and twenty pans are generally called a cubic yard, but the error of measurement in this way is very great. It is better to measure the sample in a small box made for the purpose. The swell of loose gravel above its original bulk in the bank is generally about one-fifth, so that 1 cubic yard in bank is equivalent to 1.20 cubic yards in the measuring box.

If the gold is not too fine, and many points are to be sampled, and a large quantity is to be handled from each point, it is better to wash in a rocker instead of in a pan.

On account of the difficulties mentioned, the only accurate tests are those in which the excavation of gravel is measured, and the sample taken is so large that it will include all workable sizes of stones standing in the bank. This requires the use of running water in a sluice. The latter may be 12 or 18 inches wide, and, say, 36 to 48 feet long, with slat riffles arranged for easy removal. It is not necessary to use quicksilver unless the gold is very fine, and the quantity so small that a clean-up is difficult. The gravel from distant sample points may be hauled by wagon to the sluice. For gravel carrying fine gold, the writer has used an under-current attached to the sluice, but the additional saving has never exceeded  $4\frac{1}{2}$  per cent. of the total gold.

The following figures are taken from a certain case which is selected because it typifies a large class of the gravel deposits now remaining. It also illustrates the distribution of fine gold, and the comparative results of tests made by the methods above mentioned, and washing upon a large scale. The gravel was a heavy mass, with the gold so fine as to average only  $\frac{1}{125}$  of a cent to a color. It was, therefore, very uniformly distributed through the mass. The tests were scattered over some 200 acres, and represent only the general mass of gravel, as the exposures had not developed any channel or other local concentration of coarse gold. The data from previous hydraulic washing, on 60,000 cubic yards,

showed a recovery of 5.33 cents per cubic yard. Pan tests were made at some 50 points, each test including 6 to 20 pans. The face of gravel exposed at each point, ranged from 6 to 30 feet in depth.

A single test was as follows:

Vertical depth of gravel sampled.....25.0 feet.  
 Number of pans taken.....13  
 Measured volume of sample, calculated to volume in bank. 0.119 cubic yards.  
 Total gold saved (by assay)..... 1.145 cents.  
 Gold per cubic yard of sample..... 9.65 cents.  
 Estimated percentage of bank represented in sample..... 40.0 per cent.  
 Average contents of bank if large stones are barren..... 3.86 cents.  
 Actual average of bank lies between 9.65 cents and 3.86 cents.

In order to show the range of values, a list of the results is given:

Contents Per Cubic Yard (Cents)		Contents Per Cubic Yard (Cents)		Contents Per Cubic Yard (Cents)	
<i>Upper Limit.</i>	<i>Lower Limit.</i>	<i>Upper Limit.</i>	<i>Lower Limit.</i>	<i>Upper Limit.</i>	<i>Lower Limit.</i>
9.65	3.86	2.97	1.78	6.92	4.15
7.23	2.89	1.28	0.77	2.96	1.78
4.70	2.35	16.28	9.77	10.96	6.58
1.57	0.79	4.13	2.48	3.56	2.14
12.44	4.98	0.10	0.06	8.81	5.29
2.94	1.18	6.94	4.16	6.42	3.85
10.35	4.14	2.44	0.98	3.79	2.27
5.27	2.11	5.68	2.28	4.45	2.67
20.81	10.40	6.72	4.03	5.75	3.45
14.08	8.45	11.97	7.18	.....	.....
8.91	4.46	9.47	5.68	.....	.....
11.01	6.61	0.18	0.11	.....	.....
6.80	4.08	2.07	1.24	.....	.....

Another series of tests was made by careful sluice washing with an undercurrent on quantities measured in place, and ranging from thirty to eighty cubic yards each. The face of gravel sampled

the most probable location of the channel. They will also show the presence of large stones and boulders in serious quantities, the existence of quicksand layers, etc. If gold is present, it will be brought up in the sand pump. A failure to find gold in the sand raised, may be evidence decisive enough to stop further operations, but the presence of gold, on the contrary, is not by any means decisive evidence. While drilling, the stones for a greater or less distance around the hole are churned and shaken. The finer and richer material in their interstices works loose, and flows into the bottom of the hole, so that the gold brought up by the sand pump is largely derived from this adjacent gravel. Hence, it is impossible to say what volume of gravel has yielded the gold recovered, and any figures of value per cubic yard, based upon drill hole results, is pure guesswork. Nothing could be more dangerous than to base a heavy investment upon such data.

The cost of drill holes in unknown gravel cannot be estimated closely. In favorable gravel, drilling is very rapid and cheap, but an abundance of large stones may make the work expensive, and cause the loss of many holes. The money thus spent, however, may accomplish its purpose in showing that the gravel bed is of such a character that it cannot be mined at a reasonable expense. Under average Western conditions, the total contract cost of such work will generally range from \$3.00 to \$6.00 per foot of hole.

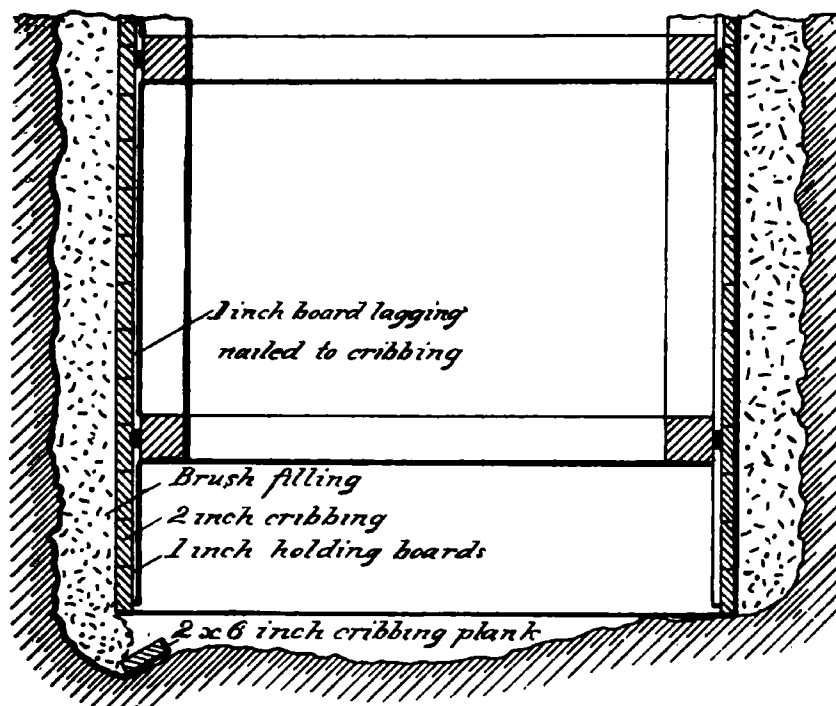
In these deposits there is no way to ascertain the structure of the pay gravel and its approximate contents, except by shafts and drifts. The depth of gravel does not usually exceed 40 to 70 feet, and much sand and small gravel must be raised with the water. A vertical centrifugal pump is, therefore, the best means of handling the flow. In one typical instance of quite open gravel, the flow reached a maximum of about 1,800 gallons per minute, while sinking a 50-foot shaft. A few weeks of steady pumping, however, reduced this to 500 gallons. The extension of drifts increases the flow, but long-continued draining has a remarkable effect in reducing it. A stream flowing over such a gravel bed,

seems to pack the interstices of its channel with fine silt, and it does not furnish water to the drained area as rapidly as might be expected.

Steam power will generally be found best, because of the temporary nature of the work, and the ease with which it may be moved from one shaft to another. Water power saves a serious daily expense, but requires a heavier first cost, and cannot be moved. It is also very difficult to adjust turbines to the increased power and speed required by the pump, as the depth increases. The usual heavy cost of such work is almost invariably due to stoppages and breakdowns, and the most careful planning is necessary to reduce these to a minimum. The pump and standpipe are best supported by an independent frame-work which can at any time be lifted out of the shaft. The pump shaft is driven by a quarter-twist belt, governed by an idler pulley which will permit the shaft to be lowered four feet before shifting its pulley.

The two standard methods available for work of this kind, are to sink by driving lagging, or to sink a caisson. With either method the shaft is apt to become distorted. Both are slow, and a caisson makes it very difficult to arrange the pumping plant. The method of driving lagging does not work well in coarse gravel, or where layers of large stones are present. Hence, in most cases, the following described plan, shown in the illustration, will be found best.

The gravel along each wall of the shaft is excavated in the form of a small trench, and the space is packed with brush. A tilted cribbing plank, 2 by 6 inches, is used to hold the brush in place, and is finally forced into position so as to form a continuation of the outer cribbing. This is held temporarily by a few 1-inch boards, nailed on and braced, as required, until a depth of four feet is gained all around, and another set of regular shaft timbers can be placed. A lagging of 1-inch boards, extending between the two sets, is then nailed on the cribbing. A shaft was sunk in this way, by skilled workmen, 47 feet in 29 shifts of 10 hours each. The water-flow was 500 to 800 gallons per



minute, but no quicksand, and only a few large stones were encountered.

In drifting, it is necessary to use the standard methods, with driven lagging and breast-boards. Two-inch lagging is generally used overhead and in the corners, and 1-inch boards at the sides and breast. This top lagging will often be found too light for the weight, and its bending causes delay and distortion of the work. In such cases, selected 3-inch lumber should be used.

In general, it may be said that, excluding stoppages, a shaft may be sunk at the rate of  $1\frac{1}{2}$  feet per 10-hour shift. Drifting should maintain an average of  $1\frac{3}{4}$  feet per 10-hour shift. The main expense is due to stoppages, the cost of plant, and the cost of bringing in skilled workmen for a temporary job.

In work of this kind, the heavy water-flow makes it almost impossible to take accurate measurements or samples. Most of

the fine sand and gravel will pass out through the centrifugal pump, and may be put through the testing sluice. This, as well as the large stones, is apt to drop its gold on being loosened in the shaft bottom. The heavy water-flow also washes out all fine gravel from the sides before it can be observed. It is therefore necessary to rely mainly upon panning and judgment during the progress of the work. After the ground has been drained for a while, it becomes possible to sample any special layers of the gravel.

#### DISCUSSION.

**Mr. Regis Chauvenet**, in discussing this paper, asked whether throwing out small stones would not cause a considerable loss on account of the gold clinging to their surfaces.

**Mr. Kirby**.—I have never made any tests to determine this point, but should expect a loss if the stones were rough. With smooth boulders I do not apprehend any trouble from this source.

**Mr. Chauvenet**.—In panning the samples would not leaf gold deceive the operator by making him think that the small particles were nuggets?

**Mr. Kirby**.—I am convinced that no man can estimate the gold in a pan by eye.

**Mr. R. C. Hills**.—Mr. Kirby has neglected to mention certain forms of placer deposits which require other methods of treatment than those mentioned in the paper. Some strongly cemented gravels must be run through a stamp mill, and certain auriferous clays require to be puddled for some hours.

**Mr. E. LeNeve Foster**.—It seems to me that, at best, one can little more than guess at the desired result. The irregularities of distribution are very great and the total amount of gold contained in a given area of placer ground thus impossible to estimate. The difficulties in the way of obtaining samples are also very great in some instances. For example, at a point on Clear Creek, about two miles below the fork, the debris in the creek bed is from thirty to fifty feet deep, and the gold all lies on the bed-rock. All the



work done here in two years did not reach bed-rock on an area exceeding one hundred square feet. This amounted to nothing more than sampling.

**Mr. Kirby.**—Very little judgment was displayed in the management of the property mentioned by Mr. Foster. A small amount of work, properly applied, would have shown that this ground contained too many boulders to be profitably worked.

## THE SELF-COOLING CONDENSER.

BY THOMAS L. WILKINSON.

Meeting of May 6, 1899.

I doubt very much whether the number of condensers used in this State of Colorado exceeds half a dozen.

There may be several reasons for this. First, the natural water supply is limited, or, at best, is very irregular, and so cannot be depended on. Second, the added cost of condensers in connection with steam plants. Third, the small amount of manufacturing done here, as compared with the East, where competition is much stronger, and cost of production is a prime factor. As this city and State continue to progress, industrial pursuits will of consequence expand. Manufacturers will seek means of lowering their cost of production. Their power must cost less, or they must get more out of it.

Mr. F. W. Dean, in his paper before the Am. Soc. Mech. Engrs., in December, 1897, on "The Reduction in Cost of Steam Power, from 1870 to 1897," says:

"Considering economics effected, it is safe to say that, without including triple-expansion engines, steam economy has steadily decreased from 20 pounds to 12½ pounds per indicated horse-power, between 1870 and 1897. This corresponds to a saving of

$$\frac{20-12\frac{1}{2}}{20}=37\frac{1}{2} \text{ per cent.}$$

"It will, in general, be observed, however, what may be said of other causes, that most of the extreme cases of economy are those in which a good vacuum has been maintained."

A non-condensing engine cannot do work by expansion, economically, below atmospheric pressure, and, when exhausted against

the atmosphere, a back pressure results. The use of the condenser is here apparent. The condenser removes the back pressure, and so more work may be done on the steam side of the piston, and the pressure becomes effective down to nearly the zero point.

Condensed steam occupies about  $\frac{1}{1000}$  of its former volume. In the jet-condenser steam is condensed by coming in contact with a jet or spray of cold water. Here condensation is instantaneous. In the surface condenser, the steam to be condensed is passed through tubes, about which cold water passes, or the cold water circulates through tubes, and the steam comes in contact with the outside of the tubes, and is instantly condensed. The total cooling surface is about one half that of the boiler heating surface.

"At sea it is found that the surface-condenser, while adding 10 to 15 per cent. to the first cost of the engine, saves from 15 to 25 per cent. of the fuel as compared with engines fitted with jet condensers, increases the durability of the boilers, if they are intelligently managed, very greatly, and gives some incidental advantages. The air pump is made half as large as with jet condensers; but the necessary addition of a circulating pump more than compensates that gain."

Common practice establishes the volume of the jet condenser from  $\frac{1}{3}$  to  $\frac{1}{2}$  that of the steam cylinder. The proportion should be made to depend on the weight of the steam discharged into it at each stroke; it is larger in small and fast-running engines.

The amount of water that is used to do the work of condensation in an engine, varies; but depends on the total heat and weight of the steam and the temperature of the injection water. If a good vacuum is maintained, say 26 inches, and the injection water does not exceed 70° F., from 25 to 30 times the amount of feed water entering the boilers, will be required to do the work of condensing the exhaust steam from the engine.

Given: I=Temperature of injection water.

D=Temperature of discharge water.

S=Total heat of the steam as it leaves the engine.

This may be taken at 1150 B. T. U.

Then:  $\frac{S-D}{D-I}$  = unit weight of injection water required per unit weight of steam.

**Example:**  $I=70^{\circ}$  F.

$D=110^{\circ}$  F. with vacuum of 28 inches.

$S=1150$  units of heat.

Therefore:  $\frac{1150-110}{110-70}=28$ , which means that 28 times as much condensing water is required as is being pumped into the boiler.

The advantage gained in horse-power with 90 pounds of steam is as follows:

<i>Point of Cut-Off.</i>	<i>Per Cent. Gained by Vacuum.</i>
$\frac{1}{2}$ .....	11
$\frac{1}{3}$ .....	12
$\frac{1}{4}$ .....	14.7
$\frac{1}{5}$ .....	17
$\frac{1}{6}$ .....	20

With 70 pounds boiler pressure the gain would be:

<i>Point of Cut-Off.</i>	<i>Per Cent. Gained by Vacuum.</i>
$\frac{1}{2}$ .....	16.5
$\frac{1}{3}$ .....	20
$\frac{1}{4}$ .....	24
$\frac{1}{5}$ .....	27.5
$\frac{1}{6}$ .....	30

The per cent. of gain in fuel is about double the per cent. of gain in power due to the vacuum. Thus, with 70 pounds boiler pressure, the difference shown by the use of the condenser would have the effect of reducing the point of cut-off from  $\frac{1}{3}$  to  $\frac{1}{4}$ .

The following table shows the percentages gained by the use of the condenser used in connection with different types of engines:

TYPE OF ENGINE.	FEED WATER PER INDICATED HORSE-POWER PER HOUR.				PER CENT. GAIN BY CONDENSING.
Name.	Non-Condensing.		Condensing		
	Probable Limits.	Assumed for Comparison.	Probable Limits.	Assumed for Comparison.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Simple High Speed ....	35 to 26	23	25 to 19	22	33
Simple Low Speed. ....	32 to 24	29	24 to 18	20	31
Compound High Speed	30 to 22	26	24 to 16	20	23
Compound Low Speed. ....	.....	*	20 to 12 <sup>3</sup> / <sub>4</sub>	18	25
Triple High Speed. ....	27 to 21	24	23 to 14	17	29
Triple Low Speed ....	.....	..	18 to 12 <sup>3</sup> / <sub>4</sub>	16	.....

The lack of a sufficient natural water supply, or the large expense in obtaining it for condensing purposes, has been the greatest drawback to the introduction of condensers. When we consider that twenty-six times as much water is needed for condensing steam as is pumped into the boilers, it naturally follows that, unless a large supply of cheap water is to be had, the engines must be run non-condensing.

The fuel economy is so generally well understood by the use of the condenser, that the problem of condensation without a large water supply has been pursued by engineers in the hope of a still further saving.

Many schemes have been devised to reduce the amount of cooling water used, as well as to cool the water used, but only with crude success. In some cases, the heated water of condensation was delivered into a pond to be used over again, when cool. Shallow pans, in great numbers, have been placed near the engine room, in racks or tiers, and also on the roof. Large surface is required, but this is a slow process, and time for cooling depends much on the temperature of the surrounding air, and the winds. Yet another way was to pump the hot water over piles of brush, thus breaking the stream into finer ones, and exposing considerable surface to the action of the air.

Experiments were made by the late James H. Fitts, of Virginia, the results of which were read before the Am. Soc. of Mech. Engrs., in November, 1892, and were in reference to an evaporative surface condenser.

The idea of the condenser was to apply currents of air to the heated discharge water of the condenser, and so, in this cooling process, the *air* became the means of condensation instead of the water, as usually employed. For this purpose, a chamber was built of wood, in such a way that the discharge from the condenser should cover large surfaces, allowing ample contact with the current of air supplied by an exhaust fan. As the water in a heated state flows over the surfaces, the air absorbs the heat of the water, and so evaporation takes place quickly. In these experiments, the cooled water required was practically equal to the amount of feed water required for the boilers. Here was a saving of twenty-five times the amount of water usually required for condensing purposes. This was the first of the trials which showed that a pound of water condensed a pound of steam. An approximate analysis of the transfer of heat in these experiments, with table of results, are as follows:

TABLE OF AVERAGE RESULTS.

Temp. in Fahr. deg.									
Boiler pressure in lbs. per sq. in. per gauge	Steam.	Cooling water—Initial.	Water in pans above diaphragm.	Water in pans below diaphragm.	Hot well.	Air.	Working strokes of air pump.	Rev. of exhaust fan per minute.	Velocity of air in feet per minute.
65	311	60	140	115	149	70	90	740	2300
Quantity of air moved in cu. ft. per min.	H. P. expended in driving fan.	Barometer in inches.	Cooling water used per hour in lbs.	Steam condensed per hour in lbs.	Vacuum in inches of mercury.	Vacuum reduced to Barometer at 30.			
6500	$\frac{1}{2}$	28	1350	900	16 $\frac{1}{2}$	18 $\frac{1}{2}$			

## APPROXIMATE ANALYSIS.

Heat in 1 lb. steam at 311 = 1208.3 B.T.U.

Heat in 1 lb. water at 149 = 149.0.

Heat rejected by 1 lb. steam = 1208.3 - 149 = 1059.3.

Of each pound of water evaporated in condenser probably  $\frac{1}{2}$  is at 140° and  $\frac{1}{2}$  at 115°.

Heat absorbed by  $\frac{1}{2}$  lbs. of water in being warmed from 60° to 140° = 57.1.

Heat of vaporization of  $\frac{1}{2}$  lbs. = 725.5.

Heat absorbed by  $\frac{1}{2}$  lbs. water in being warmed from 60° to 115° = 15.7.

Heat of vaporization of  $\frac{1}{2}$  lbs. = 299.7.

Total heat absorbed by 1 lb. water = 57.1 + 725.5 + 15.7 + 299.7 = 1098.

Thus showing the cooling water to be practically equal to the steam used by the engine. These tests showed that the application of methods of this or similar kind to be very economical and at a very small cost.

The floor space required for the cooling apparatus was small.

Enough was shown by these experiments that this method of cooling was commercially practicable. Two companies have gone into it, and many power and electric light plants are now using the self-cooling condenser.

The apparatus consists of two parts—the condenser—jet or surface—and the cooling tower.

The cooling tower is now made of sheet-iron or boiler plate, and cylindrical in form.

The size of the condenser and tower depends on the size of the plant it is operated with.

The upper three-fourths of the tower is filled with cylindrical tiling, 3 to 6 inches in diameter, and from 12 to 24 inches long. The tiling is so arranged that the water running down will cover all the exposed surface. At the bottom of the tower is a tank or well to collect the falling water. At the bottom and side of the tank is a fan which blows air up through the tower and tiling.

The exhaust from the engine passes into the condenser, where, mingling with the injection water, it is condensed. This condensed steam and injection water then enters the tower, at the side and

above the fan, and passes up through a central pipe, to a revolving distributor, near the top of the tank, just above the tiling. The distributor is mounted on ball bearings, and has four arms of piping, perforated, and swings or revolves in a manner similar to a lawn sprinkler. So the distributor revolves, by the reaction of the jets of water, which fall on the tiling, and are uniformly distributed. As the heated water runs down through the tiling the fan is blowing air up through the tower, and depriving the water of its heat, and evaporating some.

Three factors enter into the cooling of the water:

- I. Radiation from the sides of the tower.
- II. Contact of the cool air blown through the tower.
- III. Evaporation.

Evaporation is the most important of the three, as the evaporation of one pound of water in this way carries off 1,000 heat units, and condenses one pound of steam in the condenser.

Considerable cooling is done by radiation and contact of the cool air blown through the tower, so that the evaporation will be less than the amount of steam condensed in the condenser, and so the supply of extra water is not needed.

The cooled water is collected at the bottom of the tower, and ready once more to serve as injection water to the condenser. An overflow pipe is provided to carry off oil that collects.

The floor space occupied by the tower is not excessive. A 1,000 horse-power plant will require a tower 17 feet in diameter by 30 feet high. The collecting tank at the bottom of the tower is about 8 feet in diameter by 7 feet deep, and holds about 2,000 gallons of water, which is sufficient to start the plant.

The power to run the fan will be 2 per cent., and under, of the power of the engine, and may be operated by electricity, shaft and belting, or a small independent steam engine, as may be most desirable.

In some experiments made by Mr. Alberger, the temperature of the cooled water, observed under different ranges of temperature of the air, are as follows:



<i>Temp. of Air.</i>	<i>Average Temp. of Cooled Water.</i>	<i>Difference between Air and Cooled Water.</i>
20° F.....	45° F.....	25° F.
30 .....	50 .....	20
40 .....	58 .....	16
50 .....	62 .....	12
60 .....	70 .....	10
70 .....	78 .....	8
80 .....	87 .....	7
90 .....	97 .....	7
95 .....	100 .....	5

"It will be noticed that, as the temperature of the air increases, the temperature of the cooled water becomes nearer that of the former. With the temperature at 20 degrees Fahr., there is a difference of 25 degrees, and at 95 degrees Fahr., the difference is only 5 degrees, when circulating practically the same volume of air, and carrying off the same amount of heat, the circulation of the water having been reduced as the temperature is lowered. This shows plainly the activeness of the evaporation at the higher temperatures, when the air has a largely increased capacity for moisture."

In this high altitude, where the air is almost always very dry, its capacity for absorbing moisture is extremely large. The result would indicate a better showing than indicated by the above table.

A large plant in which this system of using the water over and over again, has been in constant use since 1895, some figures will be of interest.

The cooling tower was placed in the yard back of the plant, about 60 feet from the condenser. Compound engines, with a total of 750 H. P., were employed, and during the hot months a vacuum of 25 and 26 inches was easily maintained. The cooling tower is 15 feet in diameter by 33 feet high. The circulating water amounts to 1,000 gallons per minute, and the fan circulates about 100,000 cubic feet of air per minute. The whole system contains about 2,000 gallons of water. The temperature of the tank varies from 50° to 75° Fahr. The water to be distributed in the cooling tower comes in at 110° to 115° Fahr.

I have worked up some data, given by Mr. Alberger, in ref-

erence to this system, employed by an eastern manufacturing concern.

The engine is a cross-compound Harris Corliss, having a 16 x 36-inch high-pressure steam cylinder and a 30 x 36-inch low-pressure steam cylinder, making 80 revolutions per minute with 100 pounds boiler pressure.

The engine running non-condensing gave the cards showing the following:

The horse-power of the high-pressure cylinder was 109.66 and that of the low-pressure cylinder was 65.54, giving a total of 175.2 H. P. when running non-condensing.

The average mean effective pressure of the high-pressure cylinder was 36 pounds, and that of the low-pressure cylinder was 6.375 pounds.

In '95, this engine was changed from running non-condensing to condensing. A condenser was put in, and the cooling tower was placed some 150 feet from the condenser, the circulating fan being run by an extension of the shafting from the factory. The speed of the fan could be regulated to suit the condition of the weather, or could be stopped at any time.

The accompanying indicator cards show the benefits of a vacuum on this plant. An earlier cut-off is to be noted with about the same load and pressure, also equalizing the load to better advantage.

In running non-condensing the steam was admitted for 15 inches of the stroke, while condensing it was admitted but 9 inches, showing a saving of 6 inches, or a saving of 40 per cent., roughly. Cylinder condensation was slightly increased on account of terminal pressure from 29 to 10 pounds.

The fan consumed about 2 per cent. of the power under the most severe conditions. The air-pump consumed 5.7 H. P., or less than 3 per cent. of the total H. P. of the main engine. The total of 5 per cent., subtracted from the gross saving, leaves 35 per cent., or an extremely good showing for condensation by this system.

Cards, taken while the engine was running non-condensing, show that the high-pressure cylinder developed 105.28 indicated horse-power, and the low-pressure cylinder 90.6 indicated horse-power, or a total of 195.88, as against 175.20 indicated horse-power non-condensing.

The indicator cards, at my disposal, were merely specimen cards, yet from them I have drawn the combined diagram shown by Fig. 3, and it shows a very good looking diagram.

The specimen cards shown in Fig. 1 were taken when the engine was running non-condensing, and the two cylinders give a total of 175.20 indicated horse-power.

In Fig. 2, the engine was running condensing and the cards show 195.88 indicated horse-power.

In both cases the engine, aside from condensing, was operated under the same conditions of pressure and speed.

The difference, then, of 20.86 horse-power, in favor of condensing, shows an advantage of nearly 12 per cent in power. As I have said, the number of cards I had, was limited and more and better cards might have shown an even better percentage of gain by this condensing system. Even 12 per cent. would, in my judgment, warrant the introduction of this condensing system.

The gain of 35 per cent. net, as shown by Mr. Alberger, relates, of course, to the *steam* saving, while the 12 per cent. saving in *power*, as shown by my figures, results in *more power on less steam*.

Mr. J. H. Vail, engineer in chief of The Penn. Light, Heat & Power Co., of Philadelphia, in his paper on "Cooling Tower and Condenser Installation," describes the installation of this system of condensation.

The plant in question was equipped with 27 boilers, each 48 inches in diameter, 20 feet long with twenty-two 5-inch tubes. The engine capacity, and the load on the station, taxed all the boilers to the limit of their steaming capacity.

It was first proposed to enlarge the building and increase the number of boilers, but after an investigation by Mr. Vail, it was

decided to put in a cooling tower and condensers, leaving the boiler capacity as it was, thus saving the cost of additional boilers, besides the building, and obtaining a better economy, and, at the same time, greater capacity for production.

Mr. Vail further says:

"This test showed that each 48-inch by 20-foot boiler would evaporate into steam 4,281 pounds of water per hour, giving a capacity of 115,587 pounds steam per hour with every boiler in operation. Coincident with the boiler test, one 18½ by 30 Buckeye engine was using the steam from the boilers under test. Indicator cards were taken at fifteen-minute intervals for five hours. The result from the engine test and average of all cards showed a steam consumption of 46.8 pounds steam per indicated horse-power per hour.

"After the data derived from these tests had been analyzed, it was recommended that the Buckeye engine should be converted from the 18½ by 30 high-pressure engine into a 14¼ and 25 by 30 tandem compound condensing engine; also, that an additional 750 horse-power tandem compound condensing engine should be erected in the station, together with a cooling tower and the necessary condenser equipment, and that the only change in boilers should be to raise the working pressure. No increase of boiler capacity has been made.

"After investigation, the Barnard Patent cooling tower was selected as desirable to best meet the conditions existing at this plant, which were minimum floor space, and minimum weight, and a considerable elevation above floor level of engine room.

"The cooling tower is of the twin type, having two chambers, with a pair of fans supplying a strong draft of air to each chamber. The interior dimensions are 12 feet 3 inches by 18 feet by 20 feet 6 inches high.

"The tower is mounted on a substructure of steel columns and I beams, supported on substantial foundations.

"There are outside galleries and ladders affording convenient access to necessary points.

"The shell of the tower is of steel plate, properly reinforced with angle and channel irons.

"The hot water from the condenser discharge is delivered through a 10-inch wrought iron pipe, extending the whole length of each chamber, and slotted on top and perforated at the bottom, giving equal distribution to a series of distributing pipes extending across the tower, each pipe being slotted and perforated, thus insuring a very uniform distribution of water.

"Means are provided for cleaning these pipes, which is found necessary in cold weather, when the cylinder oil from the exhaust steam is liable to clog the pipes and interfere with the uniform and free distribution of the water.

"The hot water falls from the distributing pipes over galvanized wire mats.

"Each mat is suspended by galvanized iron hooks, and is easily removed for cleaning or repairs.

"In actual service it is found that the water is uniformly distributed.

"The circulation of air is furnished by two pairs of steam-driven fans, each pair of fans being mounted right and left on the same shaft, and the four fans being capable of delivering the necessary quantity of air when driven at a speed not exceeding 150 revolutions per minute.

"The air entering the tower chambers at the lower section is deflected vertically from each fan, thus avoiding cross currents, and affording a uniform blast upwards and between the mats.

"The rated capacity of each section of this cooling tower is to cool the circulating water needed to condense 12,500 pounds of exhaust steam, from an initial temperature of 132 degrees Fahr, to 80 degrees Fahr., when the atmospheric temperature does not exceed 75 degrees Fahr., nor the humidity 85 per cent.

"The following table, extracted from the log records for many months, shows details as to temperatures, speed of fans, reduction of temperature of condenser discharge, etc.

TABLE OF EXTRACTS FROM LOG-BOOK SHOWING TEMPERATURES, VACUUM, SPEED OF FANS, HEAT EXTRACTED THROUGH COOLING TOWER, ETC.

	1898.					
	Jan. 31.	Feb	June 20	July.	Aug. 26.	Nov. 4.
Time.....	9 p. m.	8 p. m.	8 p. m.	8 p. m.	8 p. m.	5:35
Temperature atmosphere .....	30°	36°	78°	96°	85°	59°
Temperature condenser discharge water to cooling tower.....	110°	110°	120°	130°	118°	129
Temperature injection water returned from tower.....	65°	84°	84°	93°	88°	92
Degrees of heat extracted by tower..	45°	26°	36°	37°	30°	37
Speed of fans at tower, R. P. M.....	36	0	145	162	150	148
Vacuum at condenser, inches .....	25½	26	25	24½	25½	25
Strokes of air pump .....	30	30	37	44	43	28
Boiler pressure, lbs. ....	110	110	120	120	120	112
Temperature boiler feed .....	212°	212°	210°	211°	213°	213°

"As previously noted, the 18½ by 30 Buckeye engine was changed to a 14¼ and 25 by 30 tandem compound condensing engine by bolting new tandem cylinders on the existing frame and making necessary alterations in valve rods, etc.

"Please note the following data:

"Revolutions, 137; steam pressure, 113 pounds; mean effective pressure, 50.16 pounds; vacuum per gauge, 26 inches; horse-power developed in high-

pressure cylinder, 163.42; horse-power developed in low-pressure cylinder, 168.48—total, 331.9 horse-power, and of this 90.52 horse-power is below atmospheric line. It will be noted that the work is divided almost equally between the high-pressure and low-pressure cylinders; all cards show similar results.

"This change in an existing engine clearly illustrates the advantage derived from the condensing system.

"In addition to the tandem Buckeye engine, a tandem compound condensing engine 20 and 36 by 42 inches, 120 revolutions per minute, Corliss type, built by the Pennsylvania Iron Works, was installed to drive a direct connected Stanley 500 Kilowatt two-phase A. C. generator. This engine works 15 to 17 hours per day.

"The usual work required from the cooling tower and condenser varies from 7 to 17 hours per day. A notable record was made on August 2, '98, when the run was from 7 a. m. until 12 midnight; and from the records the following data are extracted:

	<i>Maximum.</i>	<i>Minimum.</i>
Temperature atmosphere .....	103°	83°
Temperature condenser discharge water to tower .....	128°	106°
Temperature injection water from tower.....	98°	91°
Degrees of heat extracted, by tower.....	32°	21°
Speed of fans, revolutions per minute .....	160	140
Vacuum at condenser, inches.....	26	28
Strokes of air pump .....	50	38
Boiler pressure, pounds.....	121	100
Temperature boiler feed .....	212°	200°
Engine horse-power developed .....	900 H.P.	400 H.P.

"A continuous heavy load was carried during the entire 17 hours' run. This was not a test record, but simply daily service.

"Indicator diagrams were taken November 5, 1898, from 20 and 36 by 42 tandem compound condensing Corliss engine. The conditions were as follows:

Engine revolutions per minute .....	120
Steam pressure, pounds.....	112
Vacuum at condenser, inches.....	25
The area of the cards shows the work done in high-pressure cylinder to be .....	311.8 H. P.
And in low-pressure cylinder.....	331.5 H. P.
Total I.H.P. ....	643.3 H. P.

"Work done in low-pressure cylinder below atmospheric line, 185.1 horse-power. Simultaneously with the engine, the air pump and fan engines were indicated.

The work done by the air pump .....	13.75 H.P.
The work done by the fan engines .....	13.5 H.P.
Total external work .....	27.25 H.P.

"The amount of work, if deducted from the work done below atmospheric line in low-pressure cylinder (*i. e.*, 185.1 horse-power), leaves a net gain of 157.85 horse-power by the use of the condenser and cooling tower."

In a letter, Mr. Vail further states:

"It may be of interest to the meeting, in connection with the subject of my paper, to learn that a few days ago the 750 horse-power condensing engine, referred to therein, was operated at half load for four or five hours, at which time the fans in the cooling tower were *not* in operation—the atmospheric temperature being from 38 to 40 degrees. We were able to carry a vacuum on the condenser of 28 inches. The heated injection water pumped from the condenser to the tower at a temperature of 116 degrees, and after passing through the cooling tower was reduced to a temperature of 90 degrees. This, we find, is about the limit of load for the cooling tower when the fans are not in use."

The cooling tower, with an ordinary pump instead of a condenser, might be used with profit, I think, in another way.

Smelting works use large quantities of water in the cooling of the furnace jackets, and unless the supply is unlimited and cheap, considerable expense is attached. The water, after doing the work of cooling the jackets and absorbing the heat, could easily be pumped into one of these cooling towers and used over again.

In this case additions to the supply would be necessary to make up for the quantity of water evaporated in the tower.

This system of condensing has become so successful that its adoption after the experimental stage, has been very rapid, especially in the East, where everything in the nature of a reduction of the cost of production is most eagerly sought after. This system is superior to the condenser, which is dependent on a natural water supply, especially, when the engines are subject to great variation in load. Many of the condensers, on natural water supply, have to lift the injection water at least 16 feet, and many, higher. And this results that, in case of an overload on the engine, when the steam is admitted a greater part of the stroke, that the condenser is unable to maintain the normal vacuum. Or the vacuum may be entirely broken and the engine must be run non-condensing, or the condenser cooled off, and started again by forced injection from

an outside source. This may be appreciated in an electric railway station. In this case, the load diagram will show the tallest peak between 6 and 8 o'clock in the evening and trouble, at this time, with the condenser, would be serious, when the engines are carrying their heaviest loads.

In the case of the self-cooling condenser, the lift is never but a few feet, and the vacuum never broken.

Colorado, with its increasing tendency to manufacturing, to say nothing of the power plants in connection with mining and smelting, surely should be on the watch for all appliances which necessarily must reduce costs and increase profits. This climate is well adapted to the use of the self-cooling condensing system, on account of its dryness, and also equally well adapted on account of its limited supply of water for condensing purposes.

In a way, it is like irrigation — more to be depended on than rain.

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Two years ago I had an inquiry as to the cost of installing this self-cooling condenser in connection with two 500 horse-power engines.

I communicated with an eastern manufacturer of the highest type of hydraulic machinery, as to the cost, delivered here.

I give, in extract, the proposal. The two engines were Corliss, each 500 horse-power. The supposition was that they would consume 24,000 pounds of steam per hour.

It was proposed to furnish a — Self-Cooling Condenser to condense the steam from the above stated engines, when using steam at a rate not exceeding 24,000 pounds per hour.

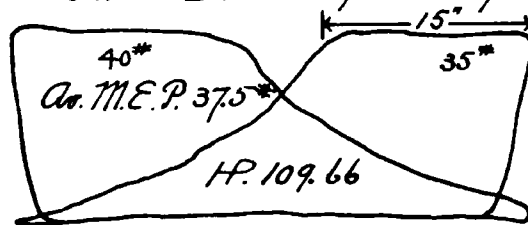
This — Self-Cooling Condenser to consist of:

One tower 18 feet in diameter and 30 feet high, substantially constructed and thoroughly painted, complete with filling, suction tank distributor, all piping in the tower, circulating fan, driving pulley, belting and suitable fan engine, electric motor, or counter-shaft with belting, as preferred. All the above to be erected com-

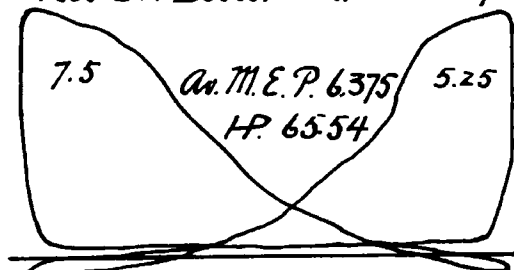


Fig. 1.

Harris-Corliss - High Pres. Cyl. 6"x36"  
 Rev. 80. Boiler Gauge 100 Lbs. Spring 40



Harris-Corliss - Low Pres. Cyl. 30"x36"  
 Rev 80. Boiler Pres. 100 Lbs. Spring 10



High Pres. Cyl. HP. 109.66

Low Pres. Cyl. HP. 65.54

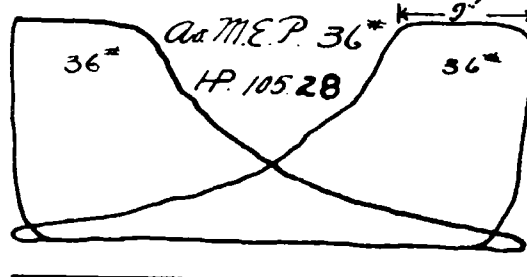
Total HP. 175.20

Without Condenser.

Fig. 2.

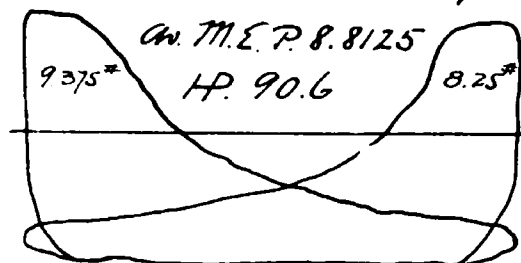
Harris-Corliss - High Pres. Cyl. 16" x 36"

Rev. 80. Boiler Pres. 100 Lb. Spring. 40



Harris-Corliss - Low Pres. Cyl. 30" x 36"

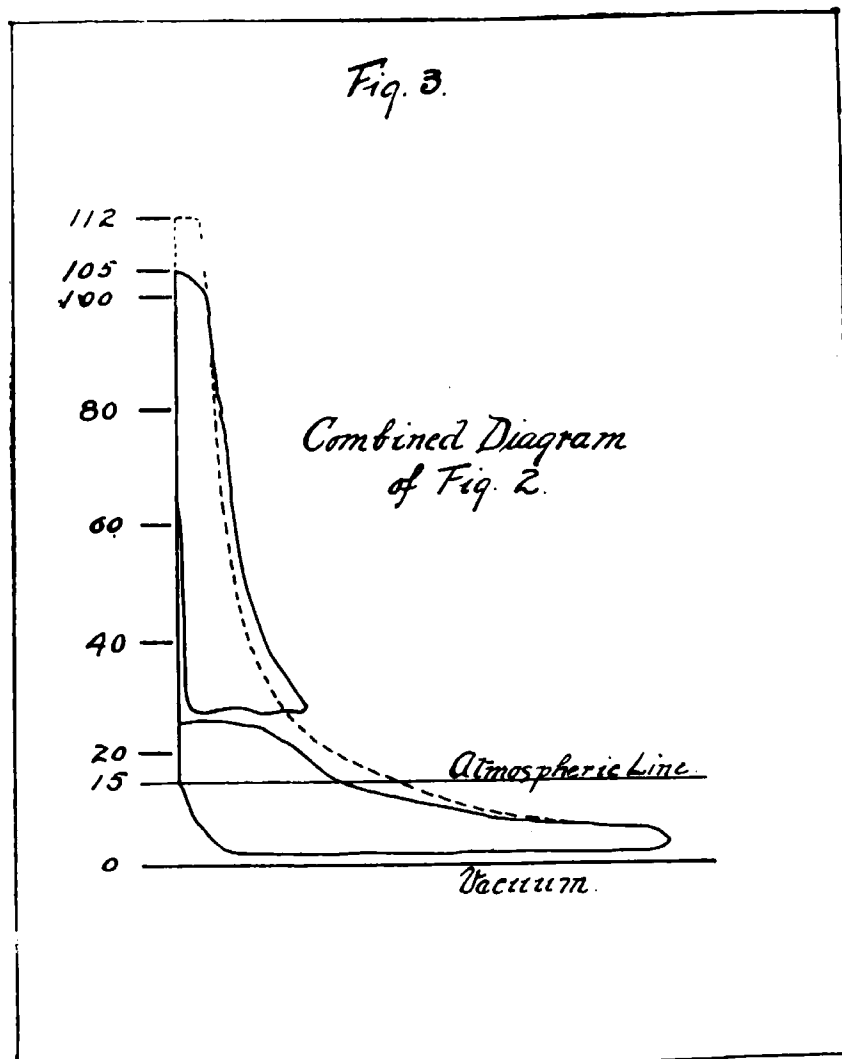
Rev. 80 Boiler Pres. 100 Lb. Spring 10



High Pres Cyl. HP. 105.28

Low Pres Cyl. HP. 90.60

With Condenser. Total HP 195.88





plete upon foundations provided by the purchaser, according to plans furnished, and ready for connection and operation.

One — Condenser with compound steam cylinders and of the jet type. This condenser to be of the latest and most approved pattern, with size for exhaust steam 18 inches, for injection, 10 inches, and for discharge, 12 inches.

One supplementary feed water heater to receive the exhaust steam from condenser pump and small fan engine.

One standard thermometer, one brass vacuum gauge, one sight feed lubricator, and suitable wrenches.

All the above to be delivered F.O.B Denver.

It was also guaranteed that this apparatus should be capable of obtaining a vacuum of not less than 22 inches of mercury, and a vacuum of from 22 to 26 inches, under all, but the most unfavorable conditions of weather, was assured, assuming the engines to be in proper condition.

All the above described apparatus to be furnished for the sum of eight thousand three hundred dollars (\$8,300).

I have no doubt but that this price, at this time, would be somewhat lower.

**"THE SUNSET TRACHYTE," FROM NEAR SUNSET,  
BOULDER COUNTY, COLORADO.**

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**By ROBERT S. BREED.**  
University of Colorado.

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Meeting of June 3, 1899.

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In the north central part of the State of Colorado is located a county, rectangular in shape, known as Boulder County. The eastern half of the county is a rolling plain, a part of the great central plain of the United States. The western half is mountainous, the western boundary line being along the first range of the Rocky Mountains. Located near the center of the county, and just at the foot-hills, on the plains, is the city of Boulder, while just at the west opening, between two of the foot-hills, is the mouth of Boulder Canon. In the canon flows Boulder Creek, and if we follow it up into the mountains, we find that about three miles west of Boulder the creek receives a tributary from a little to the north of west, known as Four Mile Creek. On following this latter creek which has also formed a canon for itself, known as Four Mile Canon, for six miles farther, we find at its western end the mining camp called Sunset. This route that I have described is followed by the Colorado & Northwestern Railroad, on its way from Boulder to Ward, a mining camp situated a few miles beyond Sunset. Just at Sunset the railroad takes higher ground by making a complete turn in the width of the canon, ascending the north side by a heavy grade. In this turn, the railroad twice cuts the bed of trachyte to be described; once in the bottom of the canon, about three-quarters of a mile before reaching Sunset, and again about

750 feet higher, on the north side of the canon, about three-quarters of a mile after leaving Sunset.

Looking down the canon from Sunset, a person would see, on the north side, West Sugar Loaf Mountain, rising about 1,500 feet from the level of the creek, the base of the mountain forming the south wall of the canon for several miles. On the north side, for some distance, there are smaller hills, each forming, in turn, about one-half mile of canon wall. About three-quarters of a mile down on this side will be seen a rounded hill, with a rise of about 900 feet on the side next the canon. This hill, we will, for convenience, call "Trachyte Hill," it being almost entirely covered, on the side next the canon, by a talus made up of trachyte.

If we now describe the two sections across the bed of trachyte made by the railroad cuttings, it will aid us in understanding the condition of things. Starting at the gulch which marks the boundary of Trachyte Hill on the west at the creek level, we find, for nearly the whole breadth of the hill, the extended talus mentioned above; then for about one hundred and fifty feet a peculiar dike-like formation, of what appears to be a brecciated eruptive granite; then about two hundred feet more of trachyte, the further edge of this being within a hundred feet or more of the gulch which marks the eastern boundary of Trachyte Hill. At the railroad cutting, 750 feet up the side of the hill, we find one bed of trachyte, bounded on the western side by a very much altered rock, probably an andesite, on the eastern side by the brecciated granite. On the side of the hill, between the two levels, we find the dike of granite bridged over by thin caps of trachyte, connecting the smaller bed of trachyte with the larger, so that it quite clearly shows the cause of the division of the trachyte into two beds at the creek level. That is, erosion has just uncovered the dike of brecciated granite at the base of the hill, and the dike, running somewhat diagonally, has nearly separated the smaller bed of trachyte from the larger.

The limits of the trachyte bed, as nearly as I have determined them, are these: The southern slope of Trachyte Hill is principally trachyte, and also the floor of the canon, (as well as) the other

side, for a short distance up the north side of West Sugar Loaf Mountain, forming the lower base of the mountain at this point. The greater part of the bed has, then, been eroded in the formation of the canon.

*The Brecciated Granite* spoken of above, is peculiar, and needs further examination to decide as to its exact nature. There is a particularly good chance to study it, both in the railroad cuttings and in a miner's tunnel which is driven in to a distance of sixty feet, just above the creek level on the north side of the canon. In the railroad cuttings, it will be found to grade into the trachyte, suggesting a partial refusing of the latter. In the miner's tunnel, the granite exhibits many cracks running parallel with each other, and nearly parallel with the surface of the hill outside. A little distance in these become farther apart; and, about fifteen feet from the surface, entirely disappear, the rock becoming solid and quite hard. In general appearance the unweathered specimens have a light gray color, and are made up of a groundmass containing large phenocrysts of feldspar and fragments averaging in size from one to several inches. These fragments are generally trachyte or granite. Of the minerals which occur in it, I have observed quartz, iron pyrites, galena, copper pyrites, siderite, and zinc blende, named in the order of abundance. The gold occurs with the sulphides, as is common in the region about Sunset.

*The Altered Andesite.* The altered rock, probably andesite, spoken of as occurring on the west side of Trachyte Hill, shows, under the microscope, a very large quantity of calcite, and every evidence of extreme alteration of all the original ingredients. A rough test shows that about 30 per cent. of the whole rock is soluble in hydrochloric acid, which acts with marked effervescence. The soluble minerals are calcite with some limonite. The microscope also shows quite an abundance of decomposed micas and amphiboloid minerals, apparently no original quartz, and some secondary quartz, a great number of apatite needles, magnetite, limonite and a groundmass of feldspars. No phenocrysts of feldspar are



present. Only a hasty examination was made, and its nature could not be certainly determined without an analysis.

As to the relation of the trachyte to these and other rocks of the same neighborhood, practically nothing can be said, as it is surrounded on all sides by rocks which have never been investigated thoroughly. The age of the rock must also be left undetermined on account of insufficient data. This bed of lava appears from a fissure in a way which leaves no evidence of violent action.

A careful search was made to see if any reference had ever been made to this trachyte in any of the geological reports or other papers, but no mention of it was found. In fact, trachytes do not seem to be very well represented in Colorado, as I have been unable to find reference to many\* others that have been at all well described.

#### MEGASCOPIC EXAMINATION.

If a person should hastily examine specimens of this trachyte from different parts of the bed, he might easily be led to conclude that he was dealing with several different trachytes, there being several distinct stages of alteration. The variety analyzed was obtained from a miner's drift, located just above the road level, in the bottom of the canon, toward the southwest limit of the outcrop on Trachyte Hill. When this was obtained it was thought to be the least decomposed of any of the varieties, but in making the slides it was discovered that the variety from near the top of the hill is somewhat fresher. The variety analyzed is light pinkish gray in color, porphyritic in structure, and, on the talus nearby, has a very dark manganese stain on the surface of the joint cracks, which is black on the surface, but light pinkish gray underneath.

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\*Trachyte from Game Ridge, Rosita Hills, Custer County, Colorado, described in several papers by Whitman Cross. See Proc. Colo. Sci. Soc., Vol. II, pp. 228-250; also, Bull. U. S. Geol. Sur. No. 150, pp. 181-182, and other papers.

Trachytes from Divide, between North and Middle Parks, and also from Elk Head Mountain, described by Clarence King, U. S. Geol. Sur., Exploration of the Fortieth Parallel, Vol. I, pp. 578-586.

In other portions of the talus, this variety, and other varieties generally, on weathered surfaces, are covered with pits, the phenocrysts of feldspar having nearly disappeared. Toward Sunset, on the level of the creek, the rock assumes, gradually, a reddish color, the coloring matter being minute specks of limonite, to be spoken of in the microscopic description. As one ascends the hill he finds quite another variety which is dark bluish or reddish gray in color, containing crystals of sphene, and, occasionally, glassy crystals of sanidine not found in the other varieties. These varieties grade into each other, the variations being chiefly in color and extent of decomposition. Weathered surfaces, generally, are more or less discolored by manganese stain, such stain keeping about the same color as the original rock. In large pieces the rock gives a metallic clink on being struck, breaking with a sub-conchoidal fracture.

In the further description, what is said will refer chiefly to the variety analyzed, that being the only one I have found time to examine at all thoroughly, although slides of the other varieties were made. The phenocrysts of feldspar are generally tabular, sometimes short, columnar crystals, rarely reaching a size of one centimeter in diameter, averaging about four or five millimeters. They are usually white, but may have either a greenish color, due to a chloritic decomposition product, or a pinkish color, suggesting orthoclase. On placing a drop of hydrochloric acid on the rock, there is frequently an effervescence about the phenocrysts of feldspar, which is probably due to the carbonates of the alkalies, as well as carbonates of the alkaline earths, as will be seen later in the analysis.

Small crystals of magnetite may be observed in the ground-mass, though in general this has a pinkish-gray color, no other minerals being apparent in this variety. In the other varieties, as mentioned above, honey yellow crystals of sphene of typical shape may be observed. These vary in size from one millimeter downward to microscopic crystals. Very rarely a crystal of undecom-

posed sanidine will be found. In all specimens flakes of limonite may be seen.

#### MICROSCOPIC EXAMINATION.

Almost all of the phenocrysts present are feldspars, these forming about 25 per cent. of the whole rock. Apatite, magnetite and sphene are sparingly present as phenocrysts.

*The Feldspars.* The microscope shows that these are of two kinds, the one an orthoclase, a more or less decomposed sanidine, the other a plagioclase, which is very nearly a pure oligoclase, as is shown by its extinction angle and the analysis.

In the *Sanidine*, twinning is very rare, though Carlsbad and quadruple Baveno twinning were both noticed. A globulaire rim is common, and in the undecomposed crystals a zonary banding was noticed. Almost all of the minerals in the groundmass were found also as inclusions, scattered irregularly through the crystals. A micropegmatic structure is found in a few phenocrysts scattered in patches throughout the crystal. The decomposition products are kaolin, secondary quartz and feldspar and carbonates. In some crystals there is a chloritic product formed with a green color, the color being due to ferrous iron, as is shown on further decomposition, when limonite is deposited, the green color disappearing. Under polarized light the decomposition products frequently give rise to colors of the second and third order. These colors do not all extinguish with the main body of the crystal, thus giving it a mottled appearance.

The *Oligoclase* occurs in phenocrysts of a diameter of one to four millimeters, averaging much smaller than the sanidine. It is not very common in comparison with the sanidine, not more than one phenocryst in ten being oligoclase. Albite twinning is found in all crystals, occasionally intergrown with Carlsbad or pericline twinning, all somewhat obscured by decomposition. A globulaire rim is quite frequently found. The inclusions and the decomposition products are much the same as in the sanidine,

except that the chloritic product never seems to be formed, the phenocrysts always being white.

*The Apatite.* This forms a very small percentage of the whole rock, but the first generation of crystals are one millimeter in diameter, and, not being decomposed, are quite noticeable. They are very characteristic crystals, both in form and in the arrangement of the needle-shaped fluid inclusions in a central core, with their long axes parallel with the long axis of the crystal. The crystals are usually about twice as long as broad, with rounded angles. These crystals were not found in all of the slides, though a later generation of needles, five or six times as long as broad, were generally found. The crystals are from one-half to one millimeter in length, and frequently show a basal jointing. Very fine apatite needles were also found as inclusions in the feldspars.

*Sphene and Anatase* The sphene and its decomposition products are the most interesting minerals in the rock. As mentioned above, crystals of fresh, undecomposed sphene occur in the variety found at the top of the hill, this being the freshest variety. The sections of the crystals are generally lath-shaped with pointed ends, though they may show the more usual shape of a section of a sphene crystal, an acute rhomb. The crystals vary in size from two-tenths of a millimeter, to one millimeter, in diameter. The characteristic twinning of sphene is quite commonly present.

In the variety analyzed, however, no sphene crystals are found, but fresh, bright yellow crystal grains of anatase occur, packed together in groups which have the approximate outline of the sphene crystals, showing both the lath and rhomb shapes. Among the grains, and forming a matrix for them, are found calcite and secondary quartz. The largest anatase crystals are one-tenth millimeter in diameter, but more frequently the crystals are about half this size. They generally have the appearance of short, square prisms or cubes, but, by careful observation, I find that these are tabular crystals, showing the basal plane, (c, 001, Dana's Miner-

alogy) and the prism face (a, 100) well developed with the octahedral face, (p, 111) showing a very slight development. On account of the high refractive index, it is impossible to make out other faces. The polarization colors are of the second and third orders. In the groundmass are sometimes found small grains, similar in appearance and in polarization colors to the undoubted anatase crystals, and these are, in all probability, anatase also, the decomposition products of the small sphene crystals. On first discovering these, I took them for perovskite, but on account of their similarity to the anatase, I think there can be little doubt as to their identity. Thus the sphene, a calcium-silico-titanite, has quite clearly decomposed to anatase, calcite and secondary quartz. I have been unable to find an account of a similar decomposition of sphene into anatase in trachytes, though as nearly as I can judge, the decomposition of the sphene in the Drachenfels trachyte, described by Irasser,\* is in all respects closely similar to this. A similar decomposition of sphene was noted by J. S. Diller in a biotite amphibole granite from Troas.† No previous mention of the occurrence of anatase in Colorado could be found.‡

*The Magnetite and Limonite.* Characteristic crystals of magnetite are found, varying in size from fine grains in the groundmass to crystals one millimeter in diameter. Very frequently they are surrounded by clouds of limonite; and the pigment in the red varieties is limonite, scattered in clouds of very fine particles throughout the whole groundmass.

*Biotite* is present in irregular corroded grains about one-tenth of a millimeter in diameter. They are quite frequent in the groundmass, and as inclusions in the feldspars, and have the characteristic color and optical properties of biotite.

*Zircon* needles, three- to six-tenths of a millimeter in length, and five to eight times as long as broad, are sparingly found. They

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\*H. Rosenbush, *Microskopische Physiographie*, Vol. II, p. 753 note, 3rd edition.

†Neues Jahrbuch, 1883, I, pp. 187 to 193.

‡Compare J. S. Randall's *Minerals of Colorado*.

are not very characteristic crystals, and I had some difficulty in identifying them.

*Augite.* In the groundmass are very rarely found greenish grains too few and small for certain identification, but corresponding in properties, as far as could be determined, with augite. Another reason for thinking them augite is that in trachytes biotite is quite commonly altered to greenish augite.

*The Groundmass.* A groundmass is generally difficult to describe, and here it is doubly so on account of the decomposition. It is made up principally of rather large orthoclase microliths and grains, showing no twinning. No plagioclase could be certainly identified. Between the microliths there seem to be the remnants of a glassy base, with some secondary quartz and kaolin. No trachyte structure was observed, though it might have been obscured by decomposition.

#### THE ANALYSIS.

The sample analyzed was from the light gray variety containing the anatase. The analysis was based on Dr. W. F. Hillebrand's "Method's of Silicate Analysis,"\* which has been found by the students in the laboratory to be the most practical of the authorities on silicate analysis. Double precipitations were used where necessary.

The sodium and potassium carbonate fusion was treated as follows: The silica was determined by evaporating with hydrofluoric and sulphuric acids, the ammonium hydroxide precipitate being ignited in the same crucible with the residue, which residue generally weighed about one milligram. The trace of silica in this was determined by fusion with acid potassium sulphate, and added to the main portion of the silica in calculation. The total iron was determined by reducing and titrating with a standard permanganate solution. The aluminic oxide was determined by differ-

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\*Bull. U. S. Geol. Sur. No. 148, 1897.

ence, deducting from the total ammonium hydroxide precipitate the trace of silica, and the total iron determined in the same portion, and the phosphoric anhydride, titanium dioxide, and zirconium dioxide determined in separate portions.

Manganese was precipitated as the sulphide, dissolved, and weighed as the pyrophosphate.

Calcium was precipitated as the oxalate, and finally weighed as the oxide. Strontium was tested for with the spectroscope, but only a doubtful trace was found.

Magnesium was determined as the pyrophosphate. Separate portions were taken for the remaining determinations.

Sodium and potassium were determined by the J. Lawrence Smith method, the potassium weighed as potassium platonic chloride, and the sodium calculated as difference between the total alkalis, weighed as chlorides, and the potassium calculated as chloride from the potassium platonic chlorides.

For ferrous iron, a rapid evaporation was made in a covered crucible with hydrofluoric and sulphuric acids, and the ferrous iron determined by titrating with a standard permanganate solution.

Titanium was determined by colorimetry. No correction for iron was made, as the small amount present could not appreciably affect the result.

Barium was determined in the same portion as the titanium, the sulphate residue being filtered off and purified by dissolving in concentrated sulphuric acid, and reprecipitating by dilution.

Water was determined by direct absorption by sulphuric acid.

Carbon dioxide was determined by absorption in potassium hydroxide.

Phosphorus was precipitated by ammonium molybdate solution, and finally weighed as magnesium pyrophosphate.

Chlorine was determined by fusion with chlorine-free sodium and potassium carbonates, and weighed as silver chloride.

Zirconium was determined by fusion in sodium carbonate, the

residue treated with hydrofluoric and sulphuric acid, and added to the main solution which was made slightly acid with sulphuric acid. Zirconium phosphate was then precipitated after oxidizing the titanium by hydrogen peroxide. The precipitate was fused and reprecipitated as the phosphate.

No trace of sulphur nor of metals precipitated by hydrogen sulphide in a hydrochloric acid solution was obtained. Fluorine was also tested for, but no certain proof of its presence could be obtained.



THE ACTUAL ANALYSIS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.
SiO <sub>2</sub>	64.08	64.88	64.03																
TiO <sub>2</sub>				18	21														
AlO <sub>3</sub>		17.62	17.79																
CrO <sub>3</sub>						60.00													
FeO		2.02	1.87																
MnO	.06	12	trace						.32	.36									
CaO		.04	1.11																
SrO	trace																		
BaO				.08	.13														
MgO	.21	.22	.23																
Na <sub>2</sub> O										4.39	4.44								
K <sub>2</sub> O										6.13	6.04								
Li <sub>2</sub> O										none	none								
ZrO <sub>2</sub>												.04	.05						
P <sub>2</sub> O <sub>5</sub>						.04	.05												
CO <sub>2</sub>															1.33	1.33			
Cl																	.19	.25	
SO <sub>2</sub>																		none	
H <sub>2</sub> O																		1.25	1.10

## THE ANALYSIS COLLATED.

Silicon dioxide .....	64.82
Titanium dioxide.....	.20
Aluminic oxide .....	17.71
Chromic oxide.....	none
Ferric oxide.....	1.95
Ferrous oxide .....	.44
Manganous oxide.....	.10
Calcium oxide.....	1.03
Strontium oxide .....	trace?
Barium oxide.....	.10
Magnesium oxide.....	.22
Sodium oxide.....	4.37
Potassium oxide .....	6.09
Lythium oxide .....	none
Zirconium oxide.....	.04
Phosphoric anhydride .....	.05
Carbon dioxide.....	1.32
Chlorine .....	.23
Sulphuric anhydride.....	none
Water.....	1.17
	<hr/>
	99.84
Less oxygen for chlorine .....	.04
	<hr/>
Total.....	99.80
Specific gravity.....	2.58

## DISCUSSION OF THE ANALYSIS.

If, with the per cents. of sodium, potassium and calcium oxides as a basis, we calculate to find the silica in the feldspars, we find that they would carry about 52 per cent. out of the 64 per cent. of silica. There is an excess of aluminum above what the macroscopic and microscopic feldspars would normally carry, which excess, calculated as kaolin, would account for about 4 or 5 per cent. more of the silica. This would still leave an excess of 7 or 8 per cent. of silica, most of which probably exists as an acid glass, cementing the microliths of feldspar, and some as quartz. There is not a sufficient excess of silica present to place the rock among

the rhyolites, though the per cent. of silica is rather high for a trachyte.

The anatase and sphene account for the titanium present. The ferrous and ferric oxides correspond to the amount of magnetite and limonite present.

The calcium and barium are not sufficient to carry all of the carbon dioxide; and probably carbonates of the alkalies are present also, as mentioned above.

The magnesium is accounted for by the flakes of biotite and the chloritic decomposition minerals.

The phosphorus and chlorine correspond to the apatite present, and the zirconium to the zircon needles.

#### COMPARATIVE ANALYSES.

In order that this analysis may be compared with the analyses of other trachytes, I have taken the liberty to quote two others. The first is a trachyte from Game Ridge, Rosita Hills, Colorado, and has been spoken of before. (See note, bottom page 219.) This analysis compares very closely with that of the trachyte just described. The other analysis is that of the well-known trachyte of the Drachenfels, Siebengebirge.

No. I. Game Ridge, Rosita Hills, Custer County, Colorado. Analyst, L. G. Eakins; Bull. U. S. Geol. Sur., No. 150, p. 182.

No. II. Drachenfels, Siebengebirge. Analyst, Deville, Prestwich's Geology, Vol. I, p. 37.

No. III. Near Sunset, Boulder County, Colorado. Analyst, R. S. Breed.

	<i>I.</i>	<i>II.</i>	<i>III.</i>
Silicon dioxide.....	66.03	65.07	64.82
Titanium dioxide .....			.20
Aluminic oxide .....	18.59	16.13	17.71
Chromic oxide.....			none
Ferric oxide.....	2.18	5.17	1.96
Ferrous oxide.....	.22		.44
Manganous oxide .....	trace		.10
Calcium oxide.....	.96	2.74	1.03
Strontium oxide .....			trace?
Barium oxide.....			.10
Magnesium oxide .....	.39	.67	.22
Sodium oxide.....	5.22	4.47	4.37
Potassium oxide .....	5.86	4.44	6.09
Lithium oxide .....			none
Zirconium dioxide .....			.04
Phosphoric anhydride.....	.04		.05
Carbon dioxide .....	trace		1.32
Chlorine.....			.23
Sulphuric anhydride.....			none
Water.....	.85	*.70	1.17
Less oxygen for chlorine.....	100.24	99.39	99.84
			.04
	100.24	99.39	99.80
Specific gravity .....	2.59		2.58

\*Ignition.

In conclusion, I would say that this paper is to be regarded as one of a series of papers issued, from time to time, from the chemical laboratory of the State University, on "The Eruptive Rocks of Boulder County." The work has been done under the direction of Prof. C. S. Palmer, to whose assistance I am greatly indebted.

# NOTES ON MINING AND SMELTING IN THE STATE OF DURANGO, MEXICO.

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BY H. VAN F. FURMAN.

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Meeting of January 6, 1900.

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The properties of the *Compania Minera de Penoles* consist mainly of the silver-lead mines which are situated about nine kilometres south of the town of Mapimi; the hacienda and smelting works at Mapimi; a narrow gauge railway, twenty-four kilometres in length, which connects Bermejillo with Mapimi, and a narrow gauge railway which connects the smelting works with the mines. This latter railway is an ordinary surface road for a distance of five and one-half kilometres, from Mapimi to Cambia, where it changes to a rack-road system, similar to the Pike's Peak Cog Railway, for a distance of three and six-tenths kilometres to Ojuela. The terminus of the rack-road, and the principal mining camp, is at Ojuela, where the main power plant, mine offices, etc., are located.

The Ojuela and San Ignacio Mines, located at Ojuela, are separated from the South Camp, where are located the Socovon, San Judas, Santa Rita, etc., by a deep arroya. The two camps have been connected by a suspension bridge, the construction of which was completed in November, 1899. This bridge has a span of over one thousand feet, and is two hundred and fifty-four feet above the bottom of the arroya. The ore from the South Camp is transported across the bridge in steel cars having a capacity of about one thousand pounds, which are operated by a tail-rope sys-

tem. When the cars arrive at Ojuela their contents are dumped into storage bins, whence the ore is drawn off into railway cars which run in on a level below the storage bins.

A tunnel is being driven into the southern mountain so as to connect the bridge railway with most of the mines of this section. When the system is completed—it is in partial operation now—the ore will be hoisted from the different shafts and winzes in buckets operated by electric hoists. The contents of the buckets are dumped into small bins, whence the ore is drawn off into the bridge cars.

Prior to the construction of the suspension bridge all the ore from the South Camp was transported on burros, over a winding trail, to Cambia, where it was loaded on the railway cars. The bridge also greatly facilitates the transportation of workmen and supplies to and from the South Camp.

According to tradition, these remarkable ore bodies were discovered and worked by the Spaniards more than three hundred years ago. Some of the old workings extend to depths of nearly one thousand feet.

The country adjacent to the ore bodies consists of limestones which are generally horizontal, or have but a slight dip, unless locally disturbed by faults and the intrusion of volcanic dikes. Many of the hills and mountains surrounding the sedimentary area are of volcanic origin. Adjacent to the ore bodies the limestones are nearly horizontal to the east, but to the west are badly faulted and twisted by a volcanic dike which intersects the formation. This volcanic intrusion antedates, and has had much to do with, the deposition of the ore. However, the ore bodies are apparently a replacement of the limestones by ores carrying lead, silver, gold, iron, arsenic, antimony, sulphur and occasionally copper. The ore bodies of the north, or Ojuela Camp, are apparently irregular masses replacing the limestone. The bottom of the great stope of the Ojuela Mine is 2,250 feet below the surface. On the 2,200-foot level, this stope is 168 timber sets (about 1,000 feet) across.

The ground above has been stoped continuously, by the present company, for a height of about 1,000 feet.

The ore bodies of the South Camp occur along a distinct break, or so-called vein, but here also the ore bodies assume the form of more or less irregular masses and are apparently replacements of the limestone.

The ores are generally oxidized, the only sulphide minerals so far encountered in any considerable quantities being galena and occasionally boulangerite. Local pockets of other sulphides have been encountered, but invariably have changed to oxidized ores below. The ores contain cerussite, anglesite, galena, boulangerite, and various oxidized iron, lead, arsenic, antimony and sulphur compounds.

The following table presents average partial analysis of the various ore as they are "bedded" at the smelting works.

<i>Name of Ore Mixture.</i>	<i>SiO<sub>2</sub>%</i>	<i>Fe<sub>2</sub>O<sub>3</sub>%</i>	<i>Al<sub>2</sub>O<sub>3</sub>%</i>	<i>CaCO<sub>3</sub>%</i>	<i>As%</i>	<i>Pb%</i>	<i>Ag. ozs. per ton.</i>
Ojuela .....	7·	30·	10·	9·	6·	23·	18·
San Ignacio ...	3·	35·	12·	6·	11·	13·	13·
Socovon .....	1·	35·	12·	5·	9·	20·	23·
Rescates .....	50·	12·	10·	18·	.....	2·	35·

In addition to the constituents given in the table, the ores carry considerable percentages of antimony and small amounts of gold, copper, manganese, zinc and sulphur. The ores designated as Rescates are low grade silicious silver ores which are purchased to flux the basic lead ores mined by the company.

These ores present a smelting problem which is somewhat unique. They are extremely basic, and carry large amounts of alumina, arsenic, antimony and some sulphur. Until recently the Rescates were not available for fluxing material. The following is an average analysis of about 600,000 pounds of base bullion

resulting from the smelting of these ores: Ph 88.6%; Sb 5.8%; As 3.6%. In these lots the antimony varied from 2.7 to 6.7%, and the arsenic from 2.3 to 5.13%. The silver contents of the bullion varies from 125 to 200 ounces per ton. The gold contents average about 1.4 ounces per ton.

Owing to the extremely base value of the bullion, and the large amount of speiss produced, the ordinary practice of lead smelting has undergone certain modifications at these works. Operating with the ordinary type of lead blast-furnace, having a deep crucible and an external lead-well, it was found to be practically impossible to keep the connection between the crucible and lead-well open. Another difficulty was encountered from the accumulation of speiss accretions in the hearth of the furnace. To overcome these difficulties the lead-wells were abandoned and the crucibles were filled up with brickwork, so as to form a shallow hearth, having a gentle slope from the rear to the front of the furnace. With this modified furnace the slag and speiss—there is practically no matte produced—are tapped in the usual way into settling pots, the slag overflowing into slag pots. At intervals of about two hours the settling pot is removed and the furnace is tapped about five inches below the slag tap-hole, for bullion. The slag and speiss which invariably accompany the tap of bullion are allowed to partially chill, when a bent iron hook is inserted. When the crust has solidified it is removed by means of the iron hook. The bullion, after paddling and skimming to remove most of the dross, is ladled into moulds.

The method proved to be so well adapted to the treatment of the ores that, in designing the new plant, which was built about two years ago, the furnaces were built without lead-wells, and with a shallow, sloping hearth. These furnaces have a separate tap for the bullion, which is located on the side near the front end (between the first and second tuyeres) of the furnace, and is six inches below the slag tap. These furnaces are thirty-six by one hundred inches in cross section at the tuyeres, have a smelting



column of eleven and one-half feet, and are provided with electric-welded steel water jackets.

The slags are somewhat unique and worthy of mention. I tried various mixtures, which produced slags having the following range of composition:  $\text{SiO}_2$  23% to 32%;  $\text{FeO}$  27% to 42%;  $\text{CaO}$  10% to 24%; but the best results were obtained with a slag having approximately the following composition:  $\text{SiO}_2$  28%;  $\text{FeO}$  35%;  $\text{CaO}$  15 and  $\text{Al}_2\text{O}_3$  12% to 14%. These slags ran well, causing little or no trouble with the lead tap, and generally no trouble from hearth accretions. Whilst not so low in silver and lead as some of the other slags, they proved to be best suited to the conditions as they existed.

The average valuable metal contents of these slags was a little less than one ounce of silver per ton and about one and one-half per cent. lead.

The speiss naturally varies somewhat in composition, but the following analysis represents the average for two weeks run under the writer's management:

Fe .....	43.4%
As .....	31.0%
Pb .....	13.2%
Ag .....	31.0 oza. per ton.
Au .....	0.22 " " "

In addition to the above constituents, the speiss contains considerable quantities of antimony, copper and sulphur. Whilst this undesirable by-product is of sufficient value in gold, silver and lead to apparently warrant its retreatment for the extraction of these metals such a course is impossible under existing conditions. This speiss problem would appear, at a first glance, to practically prohibit the economical reduction of the ores. However, with careful management, less than 25 per cent of the arsenic is reduced to speiss. Another undesirable by-product is the large quantity of flue-dust. As this carries over 30 per cent. arsenic it cannot be treated at a profit.

At present there are ten blast furnaces, four of the old and six of the new type. The four old furnaces will shortly be replaced by four furnaces of the later type. Numerous other improvements are being made which will greatly lessen the cost and facilitate the handling of ores and by-products.

# OUTLINES OF THE THEORETICAL CHEMISTRY OF COPPER.

BY CHARLES SKEELE PALMER.

Professor of Chemistry, University of Colorado.

Meeting of February 3, 1900.

This paper is written from the standpoint of one who knows but little of the practical metallurgy of copper, by personal experience, and the scope will be limited to a brief discussion of the subject as viewed from the study desk and the laboratory. The topic is a large one, and it may be noticed in passing that the time has now come when we need large separate volumes to describe, with any adequate degree of fullness, the theoretical chemistry of such metals as copper, iron, lead, zinc, tin, mercury, gold, silver, platinum and the like. Roscoe and Schorlemmer, in their volume on the metals, give forty pages to copper, and Dammer's (German) *Handbuch der anorganischen Chemie* gives one hundred and twenty pages to a bare encyclopedic statement of the more essential details of copper, unrelieved by any extended discussion or comparison of the theoretical relations of this mass of facts. A fairly complete statement and discussion of all the material known at present regarding copper probably could not be compassed in much less than a thousand octavo pages.

Copper occurs on the earth, both native and combined, in some fifty distinct minerals, besides many more new or partially identified derivatives. It is identified in the sun with a large degree of certainty. I have not noticed any occurrence in stars or

nebulae, as well established, but this is no certain negation of its occurrence in more distant stellar space, as its lines are somewhat peculiar.

The chief original mother-ore of copper on the globe seems to be the cuprous sulphide, chalcocite, or copper glance, either alone or in the twenty-odd double sulpho-salts, where it plays the basic part of the salt, as in copper-pyrites or in tetrahedrite.

The metallurgical methods for the reduction of these ores, first to the matte and then to the metal, seems to be almost as old as civilization; for we have on the one hand the evidence of the implements of the copper age, and on the other hand such testimony as that of Berthelot, who examined the slag of the old copper mines of Mt. Sinai, and states that the indications are clear that they practiced, four or five thousand years ago, essentially the same methods that are used today in treating copper ore.

In describing the physical and chemical properties of copper, we must distinguish between the conception of a metal in the physical sense, and that of a metal in the chemical sense. The physical metal is illustrated by the physical properties of such metals as iron, lead, zinc, copper, tin, silver, gold, *i. e.*, properties of opacity, weight, tenacity, hardness, durability, etc., etc. But the chemical metal is illustrated by such metals as sodium, calcium, scandium, thorium, and the properties are the basiferous qualities in general.

Considered in this light, copper is a well-defined metal, physically, but not so clearly chemically, at least in its ordinary compounds in the laboratory—that is, it is weakly acidiferous as shown by the solubility of cupric hydroxide in large excess of sodium hydroxide.

Before going into the detailed chemistry of copper let us note the significance of its chemical *locus* in the periodic sequence. Here we use the simple, consistent arrangement of the elements in independent series, the short series having seven members, the long series having seventeen members. Copper is seen to be the eleventh member of the first long series, having a “normal”

valence of one, preceding the regular dyad zinc, and following the ambiguous and paradoxical iron-nickel-cobalt group. And we find that its locality indicates that it should share with its chemical neighbors, just about the blending and overlapping of physical and chemical properties, that it does actually illustrate. For, on the one hand, it does occur with an external valence of less than one, *i. e.*, it occurs native, like the noble metals of the iron-platinum group; and, on the other hand, copper usually acts with an external valence of *two*, while its normal valence should be one. And this is worth noticing: in all ordinary soluble compounds copper acts like a dyad, as in copper sulphate, blue vitriol. We do not know any monad compound of copper and cuprous compound of salt, that is soluble in plain water. Hence we know nothing of the solution chemistry of normal copper. Such salts are fairly abundant and may be easily obtained by reduction. They are easily soluble in acids or alkalies, or salts as potassium cyanide. The cuprous hydroxide, carbonate, sulphide can be easily obtained with a little care; but the paragraphs treating of these salts are usually put in fine print in the books and most of us were probably allowed to gloss over them, thus being led to suppose that cuprous copper is difficult and irregular, and useless for a good broad chemical knowledge. Such is not the case; cuprous copper solution may be made, in acid solution, and may be handled without very much more difficulty than solutions of bismuth, or of stannous tin, and the like. Of course, the cuprous oxide in Fehling's test, the cuprous iodide, the cuprous sulphocyanate, the cuprous cyanide, may be precipitated directly from the common cupric solutions, but they are usually left there without the necessary additional practice in real cuprous solutions. But after a little more such work the student can see better how cupric solutions are above the normal, and what this means.

Again, copper is to the left of the line which marks off the elements having volatile alkyl compounds, and though copper has a hydrogen compound, it is unstable and earthy in texture.

Coming to the chemistry of copper, we notice that there are

several oxidation series, accordingly as we select a halogen, oxygen, sulphur or arsenic as the oxidizer. And here we should notice that in the state of dry chemistry or fusion, cuprous compounds are more stable, while in wet chemistry or solution, cupric compounds are more stable, at least in our oxygen atmosphere.

About four or five hundred inorganic compounds of copper have been isolated with fair reliability; probably there are at least a hundred compounds with organic acids or other carbon derivatives, so that the list of copper compounds must run up well above half a thousand.

In its occurrence as a sulphide, simple or double, copper is almost invariably a monad, as cuprous sulphide. This should be remembered, for our mineralogies usually neglect to give valence marks, and much valuable information is thus concealed or lost. The oxidation series with sulphur runs somewhat as follows: using "basic" and "acid" salts as stages. Reduced extreme, chalcocite, polybasite, tetrahedrite and tremontite, bournite and wittichenite, binnite and klaprothite, chalcostibite and wolfsbergite, guejarite—seven stages, with four more missing. The basic series with arsenic (binary) is significant and striking. But most interesting is the short series derived apparently from ortho-sulpho-ferrous acid (iron as a triad, copper as a monad) in bornite, and from the meta acid in chalcopyrite. In all these series of sulphur so far, the acid radical is supposed to be derived from a triad nucleus as arsenic, antimony, bismuth or ferric iron; but there is another sulphur series where the acid nucleus is pentad arsenic, or antimony, or tetrad tin, or the like.

The complete oxidation table of copper is simply marvelous including the reduced extreme, the hydride, then metallic copper, then indications of six stages of oxidation by oxygen (only two of which are basic in salts, while two are probably acid in their salts), and finally an extreme state with sulphur as the oxidizer, where copper may be a hexad—nine stages in all! Certainly this looks as though, in the vicinity of the inter-serial, paradoxical, ambiguous iron-nickel group, the chemical properties were carelessly

splashed over, overlapping on all the margins, and copper takes more than its share in the scramble. But here a conservative attitude may fairly well be taken. Copper does not lend its hand readily to the fundamental support of the atomic theory; very few of its compounds have been volatilized, with the exception of cuprous chloride; and for the rest of the compounds, while we write the simplest formulæ—as we do for other solids, yet candor should remind us that all such formulæ should be included in a parenthesis with the apologetic “x” or “n,” as the multiple mark. Truly what we do not know will fill even a larger book than our speculations. The atomic heat of copper is normal, so no especial suspicion attaches to its general status or atomic weight.

Copper and its compounds make up a good long list of helpful and valuable agents and reagents. Let us note some of them:

- (1) The cupric compounds are a test for ammonia.
- (2) Anhydrous cupric salts, as the sulphate, are a test for *water as such*.
- (3) Cupric salts are a test for the *metallic state* of metals like iron, in a mixture of iron particles and magnetite; hence a test for native iron.
- (4) A solution of ammonium and cupric chlorides in a solvent, and a remarkable one, for cast iron, avoiding loss from volatile hydrocarbons otherwise formed on solution of cast iron in acids.
- (5) Copper oxide has a long history as the oxidizer in the combustion of organic compounds; and, in this connection, copper foil is a destroyer of nitrogen oxides to free nitrogen in combustion.
- (6) Cupric salts, on hot bricks in Decon's process, make an excellent catalytic oxidizer with the oxygen of the air in changing hydrochloric acid to chlorine.
- (7) Cupric salts in alkaline tartrate solution make the well known Fehling's test for dextrose.

(8) Cuprous salts in ammonia, or the like, make an excellent absorption test for oxygen, as in the lead chamber in sulphuric acid manufacture.

(9) A strong solution of cuprous chloride is an excellent absorber of carbon monoxide, and an ammoniacal solution of cuprous chloride is an absorber of acetylene. A recent article by Gooch indicates that copper oxide causes acetylene to polymerize in a characteristic way.

(10) The cupric salts furnish a ready method for distinguishing between the sodium carbonate and bicarbonate, and the like.

(11) Cuprous oxide colors glass red; cupric oxide colors it greenish.

(12) Copper is one of the best conductors of heat and electricity, and its chief use lies in this latter line, its chief coming competitor being aluminum, apparently.

Among the many peculiarities of copper, there is one which is of great practical importance in the metallurgy of the metal, and will, in all probability, continue to be so. The point to which I refer is the difference that copper, as a base, displays towards silicic acid. Watt's Dictionary of Chemistry fails to note any silicates of copper, although there are several natural hydrous silicates of copper, as diopside and chrysocolla; but, so far as I know, no natural, plain cupric or cuprous silicate has ever been noted. Yet silicates of copper, with other bases, as the alkalies and alkaline earths, undoubtedly do occur, for both ancient and modern glass makers have used copper to color glass and porcelain, cuprous oxide for red, and cupric oxide for green and blue. And silicides of copper are well known. Yet, on the whole, the silicate metallurgy of fluxing off the iron from the matte, in the reduction of chalcopyrite, indicates clearly that if the crude ore be furnished with enough other base, as iron oxide, the copper may be restrained from going off in the silicate slag. This characteristic of copper is certainly striking, and needs further investigation and discussion. It is a large part of the secret of good matte



making, and this seems to be destined to be of continued importance for many years to come.

We are told that the ancients named copper from Cyprus, the island sacred to Venus, or else because the metal was the main ingredient in the speculum alloy commonly used in mirrors, the type of female vanity. Certainly the astronomical symbol for the planet Venus, a looking-glass, was also used by the alchemists to denote the metal copper. But are we now free from vanity as we boast of the electrical glory of this age, and, as we point to copper as one of the mirrors of civilization in its enormous use in electricity? Let us hope that the time may soon come when our science may boldly hold up this metal as a lasting speculum for the radiation and reflection of a clear, systematic, and fairly complete image of knowledge of the chemistry of the metals, an ideal which, at present, seems to be beyond the scope of our all too limited vision.

#### DISCUSSION.

**Mr. W. L. Austin** asked whether anything is known of the process of hardening copper which some ancient races are said to have used.

**Mr. C. S. Palmer.**—I know of no process except that of hammering. It is well known that hammering hardens copper, and the Mexicans of the present day make in this way hard copper implements which they sell to foreigners visiting their country. They are said to use wooden mallets for this purpose.

**Mr. Austin.**—I have recently visited the remains of some Aztec temples which were decorated with some very fine carvings. The rock is very hard and tough. It is certain that these people had no iron, but they had copper in great abundance. Copper wire has been found imbedded in their masonry with the obvious purpose of improving the bond. Copper was at one time worshipped by them as a god.

**Mr. D. W. Brunton.**—Referring to Mr. Palmer's statement that the original ore of copper is probably, in nearly all cases,  $\text{Cu}_2\text{S}$ , I

would say that the most careful investigations at Butte, Montana, have led to the conclusion that, in the deposits there, the original ore was chalcopyrite, and that the  $\text{Cu}_2\text{S}$  is a derivation from this.

**Mr. Palmer.**—Has anyone here ever known of the occurrence of cupric sulphide as an ore of copper?

There was no affirmative to this question.

**Mr. Austin** referred to the alkaline sulphide process for separating copper and nickel. In this process the mixture of metallic sulphides is fused with salt cake. The sulphide of nickel settles to the bottom, leaving the other sulphides on top.

**Mr. Brunton** referred to the deposition of metallic nickel from a gas known as nickel carbonel, a process which is now being experimented upon by the Sundbury Copper Company, in anaCda.

## NECROLOGY.

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CHARLES A. MARTINE.

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On the 22d day of June, 1900, Charles Martine died at St. Luke's Hospital in Denver. He was born October 14, 1839, in Munich, Bavaria. The Martine family were originally French Huguenots, but, during the persecutions, fled to Bavaria. Charles A. attended the Munich government schools, and entered the University of that city, from which he graduated in 1857. In August of the same year he came to America and located in New York City where, for three years, he held a tutorship in Columbia College. During the civil war, he served from 1861 to 1865 in the Engineer Corps of the U. S. Navy. In May, 1866, he came to Colorado, locating at Central, but the following year went to Georgetown, remaining a resident of that place the rest of his life. He turned out, by the amalgamation process, the first bars of silver produced in the State, and was the first person to engage in the shipping of ores to the smelters in Europe, in which business he continued until July 12, 1880. He was a man of considerable scientific attainments, and his advice was frequently sought. In later years he engaged in mining on his own account, being the owner of the McClellan and other properties on Leavenworth Mountain. He was one of the earliest members of the Society, as he was one of seven who were elected at the first regular meeting of the Society, held January 2, 1883.

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CHARLES H. TOLL, Denver.

Died December 4, 1901.

MAJOR HENRY FULTON, Boulder, Colo.

Died December 6, 1901.

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